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Notices

of the American Mathematical Society

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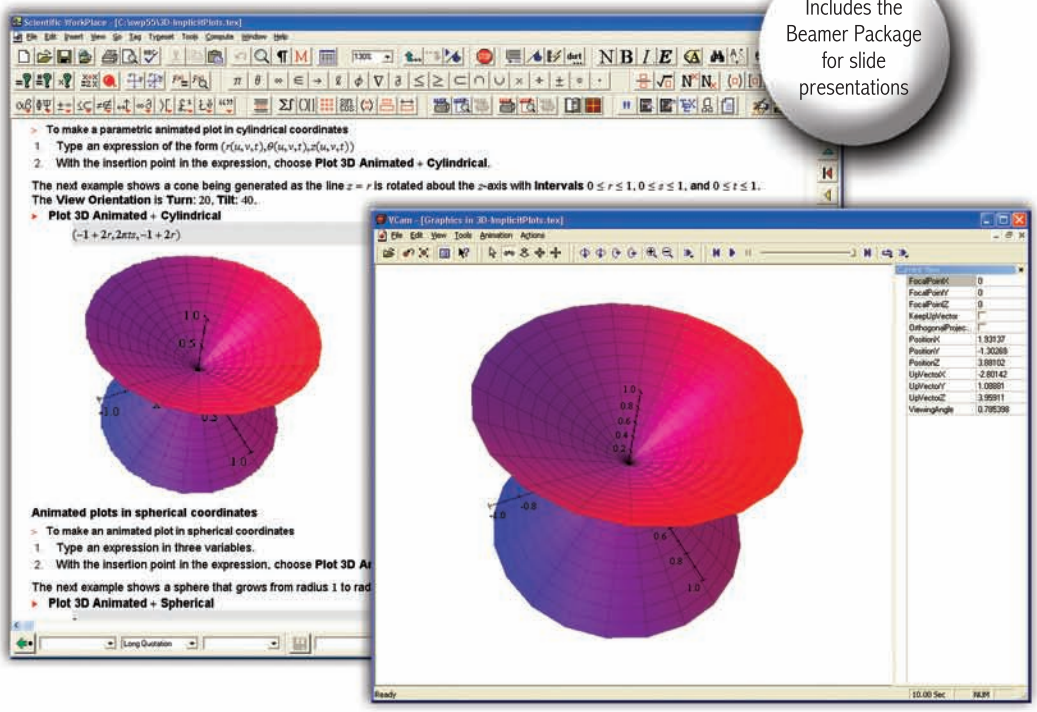

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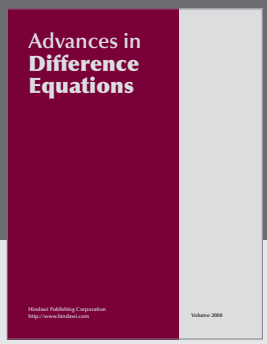

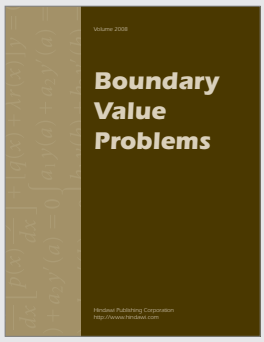

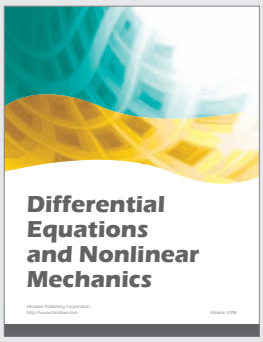

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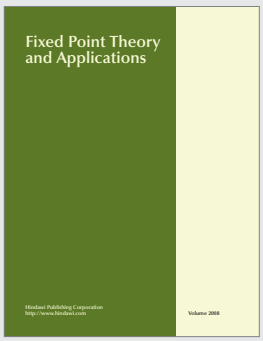

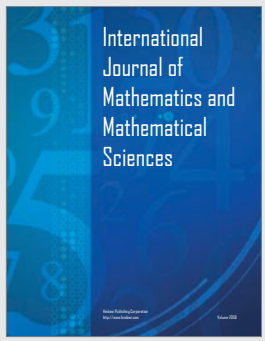

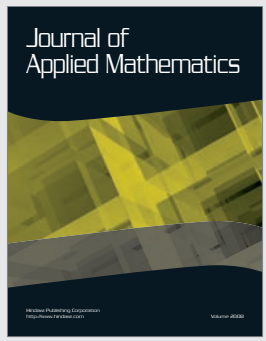

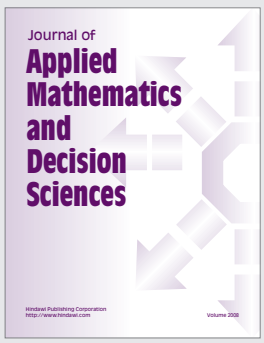

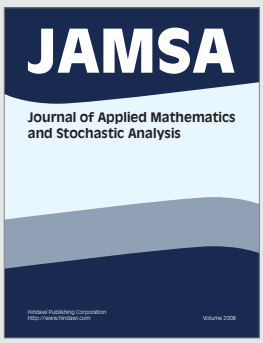

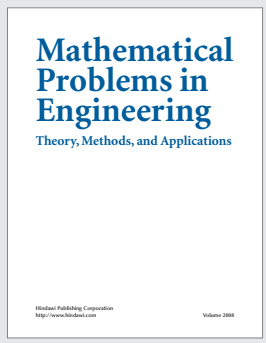

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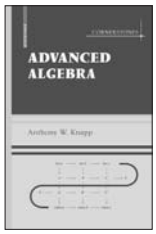

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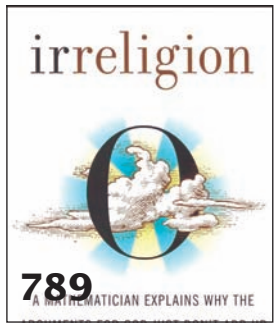

Sir Thomas and Lady Ada Heath. Photo courtesy of the National Portrait Gallery, London.

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776 A Centennial Celebration of Two Great Scholars

Shirley B. Gray

Important mathematical works of antiquity by Archimedes and Euclid became definitively available to the modern world through the labor of scholars a century ago. The author tells the story of these scholars and their work.

798 Computable Fields and Galois Theory

Russell Miller

Galois theory, in part, is about finding roots of polynomials, and in part about the impossibility of finding roots. Most mathematicians are familiar with the latter, at least for certain rational equations of the fifth degree. The author applies modern computability theory to a discussion of algorithms for finding roots, or for determining that they cannot be found.

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Desperately Seeking Mathematical Truth

We mathematicians have a naive belief in truth. We prove theorems. Theorems are deductions from axioms. Each line in a proof is a simple consequence of the previous lines of the proof, or of previously proved theorems. Our conclusions are true, unconditionally and eternally. The Babylonians' quadratic formula and the Greeks' proof of the irrationality of $\sqrt{2}$ are true even in the Large Magellanic Cloud.

How do we know that a proof is correct? By checking it, line by line. A computer might even be programmed to check it. To discover a proof, to have the imagination and genius to conceive a chain of reasoning that leads from trivial axioms to extraordinarily beautiful conclusions—this is a rare and wonderful talent. This is mathematics. But to check a proof—any fool can do this.

Still, there is a nagging worry about this belief in mathematical certitude. In 2000 the Clay Mathematics Institute announced million dollar prizes for the solution of seven "Millennium Problems". Solve one of the problems and receive a million dollars. According to CMI's rules, two years after the appearance of the solution in a "refereed mathematics publication of worldwide repute" and after "general acceptance in the mathematics community", the prize would be awarded.

But why the delay? Surely, any competent person can check a proof. It's either right or wrong. Why wait two years?

The reason is that many great and important theorems don't actually have proofs. They have sketches of proofs, outlines of arguments, hints and intuitions that were obvious to the author (at least, at the time of writing) and that, hopefully, are understood and believed by some part of the mathematical community.

But the community itself is tiny. In most fields of mathematics there are few experts. Indeed, there are very few active research mathematicians in the world, and many important problems, so the ratio of the number of mathematicians to the number of problems is small. In every field, there are "bosses" who proclaim the correctness or incorrectness of a new result, and its importance or unimportance. Sometimes they disagree, like gang leaders fighting over turf. In any case, there is a web of semi-proved theorems throughout mathematics. Our knowledge of the truth of a theorem depends on the correctness of its proof and on the correctness of all of the theorems used in its proof. It is a shaky foundation.

Even Euclid got things wrong, in the sense that there are statements in the *Elements* (e.g., Book I, Proposition 1) that do not follow logically from the axioms. It took 150 years after Leibnitz and Newton until the foundations of differential and integral calculus were formulated correctly, and we could backfill proofs of much eighteenth and nineteenth century mathematical analysis.

Similar problems plague us today. Consider the two most highly publicized recent successes of mathematics. It took several years to confirm the correctness of Wiles' proof of "Fermat's Last Theorem". A mistake was found in the original paper, and there still remained questions about the truth of other results used in the proof. There were also arguments about the completeness of Perelman's proof of the Poincaré conjecture, the first of the Millennium Problems to be solved. How many mathematicians have checked both Wiles' and Perelman's proofs?

I certainly don't claim that there are gaps in Wiles' or Perelman's work. I don't know. We (the mathematical community) believe that the proofs are correct because a political consensus has developed in support of their correctness.

The classification of the finite simple groups provides another example. There is still uncertainty about whether there is a complete proof of the classification, and, if there is a proof, exactly when the theorem was proved. After the classification was supposedly finished, Danny Gorenstein wanted to write an exposition of the proof. He would reread the papers and find mistakes. He could always patch things up, but until he did, the "theorems" in the original papers were, according to the rules of our profession, not theorems but unproven assertions. We mathematicians like to talk about the "reliability" of our literature, but it is, in fact, unreliable.

Part of the problem is refereeing. Many (I think most) papers in most refereed journals are not refereed. There is a presumptive referee who looks at the paper, reads the introduction and the statements of the results, glances at the proofs, and, if everything seems okay, recommends publication. Some referees do check proofs line-by-line, but many do not. When I read a journal article, I often find mistakes. Whether I can fix them is irrelevant. The literature is unreliable.

How do we recognize mathematical truth? If a theorem has a short complete proof, we can check it. But if the proof is deep, difficult, and already fills 100 journal pages, if no one has the time and energy to fill in the details, if a "complete" proof would be 100,000 pages long, then we rely on the judgments of the bosses in the field. In mathematics, a theorem is true, or it's not a theorem. But even in mathematics, truth can be political.

—Melvyn B. Nathanson
Lehman College (CUNY)
and CUNY Graduate Center
melvyn.nathanson@lehman.cuny.edu

Letters to the Editor

Remembering Alex Rosenberg

The obituary notice for the influential mathematician Alex Rosenberg in the May 2008 issue touched a chord in my memory, for my father and Alex Rosenberg were colleagues at Northwestern University when I was a small child. I fondly recall one summer evening when my father was entertaining the family after dinner by recounting the amusing pseudonyms used by various mathematicians. The telephone rang, interrupting an etymological discussion of the name A. C. Zitronenbaum. My father lifted the receiver, listened for a moment, and then chuckled. "Why, hello, Alex. We were just talking about you!"

—Harold P. Boas
Texas A&M University
boas@math.tamu.edu

(Received May 2, 2008)

What Bombelli Knew

I refer to Sanford Segal's review of John Derbyshire's book *Unknown Quantity* in the May 2008 issue of the *Notices,* page 584. We are told, I am sure correctly, that 4 is one of the solutions to $x^3 = 15x + 4$, but Segal, Derbyshire, and others have been strangely reluctant to disclose the other two solutions. These are in fact $-2 - 3^{0.5}$ and $-2 + 3^{0.5}$, computed from finding the roots of complex numbers. There is no evidence that these other two solutions were known to Bombelli.

—Peter L. Griffiths
London
lowdith73@yahoo.com

(Received May 4, 2008)

Memories of Elbert Cox and Removing Barriers

Two items in the May *Notices* caught my attention.

a) "Evansville honors the first black Ph.D. in mathematics and his family", by Talitha Washington. There is reference to Elbert Cox as the first African-American to to get a Ph.D. in mathematics. His supervisor was W. L. G. Williams. Prof. Williams was a teacher of mine at McGill and is the father of my wife Christine. She got a Ph.D. in mathematics at Yale University. Elbert was a regular visitor to the Williams home in Ithaca and it is reported that he used to bounce Christine on his knees—she was still an infant!

b) The other item mentions an award to the University of Iowa mathematics department for their leadership in recruiting and developing "underrepresented" minorities.

I should like to add that I was appointed to the council of the AMS in the late 1960s and early 1970s. I had been interested in recruiting into the graduate program at Penn State members of the groups referred to at that time as "disadvantaged". I proposed to the council that a committee be appointed to consider ways and means by which this might be done. The term "disadvantaged" referred to women, blacks (now referred to as "African-Americans"), Hispanics, Native Americans, and others. The committee, comprising outstanding scholars, worked diligently and, whether through its stimulus, or more likely, spontaneously, there arose the "National Association of Mathematicians" and the "Association for Women in Mathematics".

I was optimistic at that time and predicted that all racial and sexual barriers would disappear by the end of the century. It is gratifying to see that much progress has been made, but much work remains to be done.

—Raymond Ayoub
Pennsylvania State University
rga1@psu.edu

(Received May 5, 2008)

More on "Visualizing the Sieve of Eratosthenes"

Since the publication of "Visualizing the Sieve of Eratosthenes" in the May 2008 issue of *Notices*, I have heard from a number of correspondents.

Brian Hayes has informed me of some similar work by himself and others which has appeared previously and which, had it been available at the time I prepared my *Notices* article, I would have acknowledged. One easily accessible such noted by Hayes is the article by J. J. Ventrella available at http://www.divisorplot.com.

William Keith, Zachary Strider McGregor-Dorsey, Oliver Rudolph, and others have offered explanations of the parabolas I mentioned and which Bill Casselman indicated on the cover of the May issue. I would like to thank them for their correspondence and insights.

A number of people have written requesting software. I have provided some updated software for creating and exploring the Sieve images at http://www.guffy.net/sieve. I had previously requested that people write me for the software. However, the website now provides a direct link to the software.

I would also like to mention that the Sieve article in the *Notices* was an outgrowth of work that I had started in 2003. In 2004 I posted a preliminary result of this work on my website at http://www.guffy.net/matrix.htm and then asked for comments in an Internet news group. The 2004 news group discussion which ensued has been archived and can be viewed at http://www.mathkb.com/Uwe/Forum.aspx/math/13894/An-interesting-matrix.

—David Cox
North Carolina State University
sieve@guffy.net

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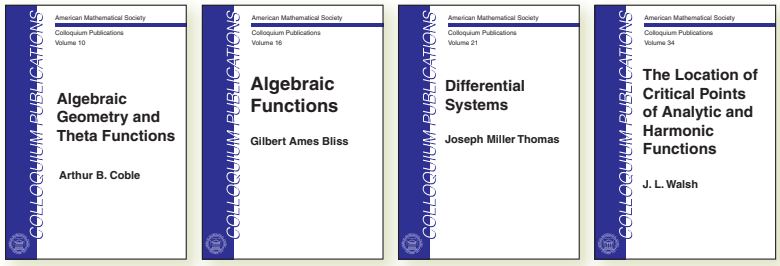

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A Centennial Celebration of Two Great Scholars:

Heiberg's Translation of the Lost Palimpsest of Archimedes—1907
Heath's Publication on Euclid's Elements—1908

Shirley B. Gray

The 1998 auction of the "lost" palimpsest of Archimedes, followed by collaborative work centered at the Walters Art Museum, the palimpsest's newest caretaker, remind *Notices* readers of the herculean contributions of two great classical scholars. Working one century ago, Johan Ludvig Heiberg and Sir Thomas Little Heath were busily engaged in virtually "running the table" of great mathematics bequeathed from antiquity. Only World War I and a depleted supply of manuscripts forced them to take a break. In 2008 we as mathematicians should honor their watershed efforts to make the cornerstones of our discipline available to even mathematically challenged readers.

Heiberg

In 1906 the Carlsberg Foundation awarded 300 kroner to Johan Ludvig Heiberg (1854–1928), a classical philologist at the University of Copenhagen, to journey to Constantinople (present day Istanbul) to investigate a palimpsest that previously had been in the library of the Metochion, i.e., the "daughter" or "sharing" house of the Church of the Holy Sepulcher in Jerusalem. Heiberg's proposal to the foundation was to make photographs of a "damaged and readable, but very hard to decipher" Byzantine Greek work on vellum. Over its thousand year history, the palimpsest had journeyed between these two Greek Orthodox church libraries. Indeed, the overscript is a euchologion most likely written near the turn of the thirteenth century by a priest of the church. Today the palimpsest contains four illuminated plates, presumably of Matthew, Mark, Luke, and John.

Johan Ludvig Heiberg. Photo courtesy of The Danish Royal Society.

Heiberg was eminently qualified for support from a foundation. His stature as a scholar in the international community was such that the University of Oxford had awarded him an honorary doctorate of literature in 1904. His background in languages and his publications were impressive. His first language was Danish but he frequently published in German. He had publications in Latin as well as Arabic. But his true passion was classical Greek. In his first position as a schoolmaster and principal, Heiberg insisted that his students learn Greek and Greek mathematics—in Greek. Indeed, he made his debut into public life at the age of thirty when he led a movement to require the study of Greek in all Danish schools. He even founded a Greek social society that continued until after his death.

He had entered Copenhagen University as a young man of fifteen and immediately took up mathematics, Greek, and classic philology. He completed his doctoral work at the inordinately young age of twenty-five with a thorough, very meticulous chronology of the works of Archimedes. He was especially attracted to *The Sand-Reckoner* problem dealing with the number of grains of sand needed to fill the universe. His capstone graduation trip was naturally to Italy to investigate more deeply the background of his dissertation, *Quæstiones Archinedeæ*.

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The author thanks Nigel Wilson (Lincoln College, Oxford), Adrian Ponce (Jet Propulsion Laboratory, Pasadena, CA), Akif Tezcan (University of California, San Diego) and Erik Petersen (Det Kongelige Bibliotek).

Photograph courtesy of the author.

The Metochion faces the main courtyard and entrance to the Church of the Holy Sepulcher in Jerusalem.

Upon returning to Denmark he initiated a career of translating classical manuscripts. While not abandoning Archimedes, his first academic recognition came through a parallel interest in various editions of Euclid. Dijksterhuis, the Dutch scholar, would later write that "If a reader was to become acquainted with the work of a writer of Archimedes' level, an understanding of the *Elements* of Euclid was—and still is—a prerequisite, though by no means a sufficient preparation." Heiberg's publications underscore his multiple talents. In addition to mathematics, he practiced his textual skill by putting the 1269 Latin works of Flemish Dominican Willem van Moerbeke back into their original Greek. Heiberg's work was recognized by his appointment (1896) to be professor at the University of Copenhagen.

For over two decades and in several publications, Heiberg refined the work on classical Archimedean manuscripts initiated in his doctoral dissertation. When he wrote his proposal to the Carlsberg Foundation, Heiberg was aware of two major unexplored references. First, there was mention of a palimpsest in a travel book, *Reise in der Orient* (Leipzig 1846), written by the German biblical scholar Constantine Tischendorf and translated into English by W. E. Shuckard (London 1847). A half century later, A. I. Papadopoulos-Kerameus cataloged 890 Greek manuscripts at the church in Constantinople. This catalog, which was published in 1899, came to the attention of H. Schöne in Germany, who then alerted Heiberg in Denmark of the possibility of finding additional Greek mathematics palimpsests.

Following the award of the Carlsberg grant and subsequent travel, Heiberg arrived in Constantinople in 1906 for the first of two trips. He painstakingly transcribed the original Greek underscript using only a magnifying glass and various light sources. Judging by the proposal, one feels that Heiberg probably left Copenhagen thinking he could successfully photograph the palimpsest and then later read the prints at his leisure upon returning home to Denmark. Being a meticulous scholar, Heiberg returned to Constantinople in 1908 to refine and check his earlier work. Then satisfied with his notes, he was joined by a German colleague, H. G. Zeuthen, who assisted him in verifying a transcription of the text. This watershed discovery was announced in *Eine neue Archimedes-Handschrift*, Hermes XLII (1907), pp. 235–297.

This author attended the 1998 auction at Christie's in New York and has examined the palimpsest both prior to and after its Christie's sale; also, the one stolen page now in the Cambridge University Library, Add. 1879.23. In addition, the 65 photos taken by Heiberg in 1906 were examined both when on loan to the Walters Art Museum in Baltimore and in their home in Copenhagen's Royal Library. The condition of the palimpsest is poor. Mildew over the past century has marked some pages with

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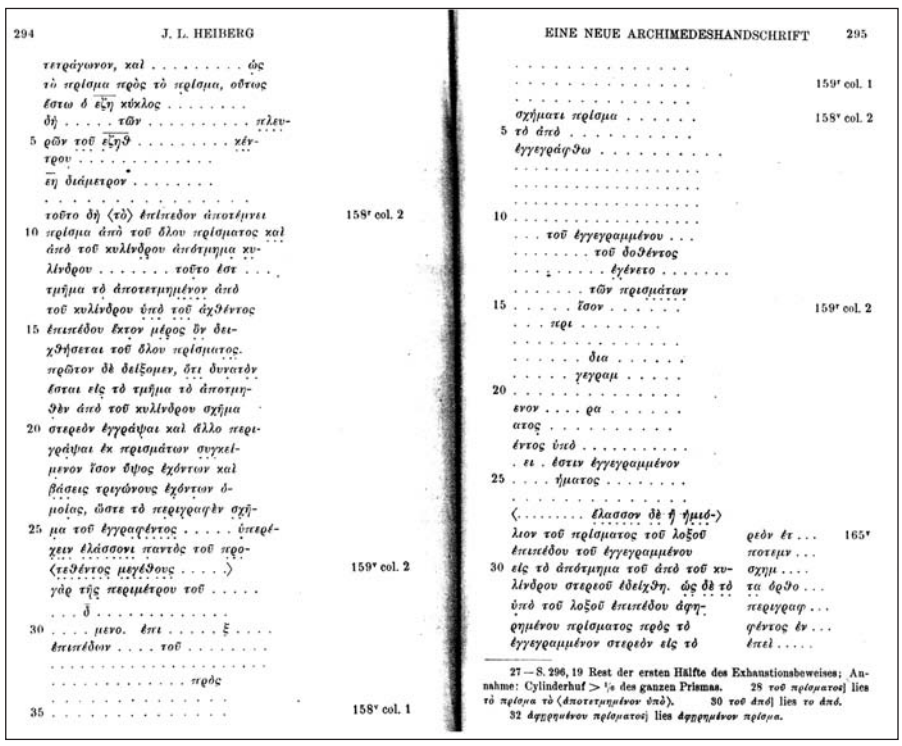
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EINE NEUE ARCHIMEDESHANDSCHRIFT 295

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. . . . . 159r col. 1
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εἰς τὸ ἀποτμημα τοῦ ἀπὸ τοῦ κυ- σχημ . . . .
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ρημένου πρίσματος πρὸς τὸ φέντος ἐν . . .
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27 — S. 296, 19 Rest der ersten Hälfte des Exhaustionsbeweises; Annahme: Cylinderhuf > ½ des ganzen Prismas. 28 τοῦ πρίσματος] lies τὸ πρίσμα τὸ ⟨ἀποτετμημένον ὑπὸ⟩. 30 τοῦ ἀπὸ] lies τὸ ἀπὸ. 32 ἀφῃρημένου πρίσματος] lies ἀφῃρημένον πρίσμα.

Heiberg's original publication (1907) draws attention to the missing portions of Propositions 14 and 15 in the *Method*. Even with the most advanced technology, it may not be possible to image these critical sections, thus leaving mathematicians to speculate on Archimedes' approach.

a purple stain. Browning around the edges suggests that in addition to being quite aged, the palimpsest may narrowly have escaped a fire. Far worse today, much of the text that Heiberg tediously translated is no longer visible. Thus the photos taken in Constantinople one century earlier have become a valuable guide for contemporary scholars. The photos, as enlargements of the original leaves, are easier to read than the Archimedean underscript visible in 2008. In translating the Greek mathematics, Heiberg sequenced the pages and identified the original book, i.e., *Equilibrium of Planes, Floating Bodies, Method of Mechanical Theorems, Spirals, On the Sphere and Cylinder, Measurement of the Circle,* and *Stomachion*. Of these seven texts, four (see later sections, each marked with an asterisk) were already known from other sources. Also, readers might note that the *The Sand-Reckoner* entered our literature from other sources and is not in the palimpsest.

In the 1450s Pope Nicholas V commissioned a new translation of Archimedes. This richly illuminated manuscript, considered to be one of the Vatican's treasures, ends with "Finis librorum Archimedis quos transcrivi iussit dominus Franciscus Burgensis sempre deo laus". Basilese, 1544. (Note the small cone, sphere, and cylinder in Archimedes' left hand.)

Photograph above courtesy of the Vatican Library.

There is an additional challenge. When the thirteenth century scribe set about to scrape off the original Archimedean manuscript to reuse the parchment for a prayer book, he simply selected the leaf he felt was in the best condition. Thus today sequential pages of the overscript in the legible prayer book represent randomly selected leaves of unorganized mathematics in the underscript. One can imagine the chaos of mixing the pages of this issue of the *Notices* translated into a foreign language and then trying to read 178 pages of mathematics overwritten by religious text. The ancient Greek mathematics in the underscript, if visible, is faded, tedious to translate, and randomly organized when compared to its original source. In brief, this might be called a scholar's nightmare. Fortunately, the very best are hard at work on the translation. Nigel Wilson at Lincoln College, Oxford, and Reviel Netz, Department of Classics, Stanford University, are the principal scholars involved in the task.

Another factor emerges. Nigel Wilson makes the point that while Euclidean geometry was a significant portion of the quadrivium and thus widely studied in the Middle Ages, Archimedes was primarily a source of interest only to the connoisseur of mathematics (Wilson, 1999). There are numerous manuscripts and editions of Euclid in European libraries, but the textual transmission of Archimedes across the centuries "hangs by a slender thread." There are not many occasions when today's translators can catch a glimpse of past experts at work on Archimedes. Among Heiberg's papers in Copenhagen is a hand-written manuscript listing where he found references to copies of Archimedes and, all too frequently, their later disappearance. Primarily his sources, bridging centuries of time, were found in the Vatican, other Italian libraries, and Basel. For example, Heiberg wrote that Leonardo da Vinci had found one copy in the library of the Bishop of Padua, and noted Renaissance men truly did seek ancient Greek manuscripts to translate mathematics. The Dutch Archimedean scholar E. J. Dijksterhuis continued Heiberg's "philological investigations" of manuscripts and printed editions. Wilson, Heiberg, and scholars before them have noted where they were unable to trace a missing copy.

As mathematicians, readers of the *Notices* will recall classic problems from each of the books. We briefly remind readers of their contents.

Equilibrium of Planes*

Archimedes, in writing on rectilinear figures, followed the century-earlier investigations of Aristotle, but constructed propositions knowing the mathematical dictates of Euclid. This treatise uses the method of exhaustion to concentrate on the center of gravity of triangles, trapezoids, and parabolic segments. We thus find a veiled suggestion of modern calculus as well as the principle of moments, also known as the law of levers. Archimedes has been called the "Father of Classical Mechanics".

Floating Bodies

The palimpsest is the only known surviving copy of *Floating Bodies* in the original Greek. In this text we find the principle of buoyancy. Familiarity with these investigations was probably a factor in Archimedes' legendary naked run through the streets of Syracuse yelling the famous "Eureka, Eureka!" Similarly, his understanding of hydrostatics and levers combined to supposedly move a floundered ship built for King Hiero. This led to "Give me a place to stand and I can move the Earth." Travelers to third world countries may still see the Archimedean water screw being used to irrigate fields, drain marshes, or empty bilge water from a boat.

Spirals*

Unlike many expressions in mathematics, the Spiral of Archimedes $r = a\theta$ seems to be properly named. He appears to be the very first of a long list of distinguished mathematicians, e.g., Descartes, Fermat, Bernoulli, and Euler, to investigate its special properties. In particular the area bounded by

the Spiral is one of 28 propositions in this text. He wrote, "The space bounded by the spiral and the initial line after one complete revolution is equal to one-third of the circle described from the fixed extremity as center, with radius that part of the initial line over which the moving point advances in one revolution." [$A = \frac{1}{3}\pi(2\pi a)^2$].

On the Sphere and Cylinder*

George F. Simmons calls Archimedes' discovery of the formula for the volume of a sphere "one of the greatest mathematical achievements of all time" (Simmons, 1992). There are several levels of importance. Here Archimedes described to Eratosthenes, his friend at the Museum in Alexandria, a "most wonderful demonstration" that the sum of slices of cross sections of a sphere and a cone would counterbalance the sum of slices of a related cylinder. Then, by his choice of words in Greek, we are certain that Archimedes recognized the difference between a heuristic investigation, $\theta\epsilon\omega\rho\epsilon\iota\nu$, and the very cornerstone of mathematical reasoning—proof or $\alpha\pi o\delta\epsilon\iota\kappa\nu\upsilon\nu\alpha\iota$. Moreover, he was applying the principle of the lever balancing a center of gravity from classical mechanics. By thinking in terms of solids being dissected into slices, he was again on the brink of modern calculus. Heiberg translated the same passages into German as "……dass er sie vorher durch die Mechanik gefunden, nachher geometrisch bewiesen habe" (Heiberg, 1908).

The one leaf in the Cambridge Library, now known to be taken from *On the Sphere and the Cylinder*, is thought to have been stolen by Tischendorf, for it was sold by his executors in 1876. This leaf is embedded in air-tight plastic and its condition is strikingly better than the heavily mildewed manuscript auctioned at Christie's. Both the leaf and the manuscript are scorched at the edges and thus must have been in a fire. We owe the identification and transcription of this leaf to Nigel G. Wilson who also prepared much of the text for the Christie's catalog.

Measurement of the Circle *

The most significant contribution of this particular text is Archimedes' method for approximating a value for π. (Both he and the early Chinese mathematician Liu Hui (ca. 250 AD) used only words, not a symbol, to express the ratio of the circumference of a circle to its diameter. The symbol π did not appear until much later in the eighteenth century.) Once again, his approach was the method of exhaustion. This time he calculated a difference in areas by successively inscribing and circumscribing regular polyhedra of 6, 12, 24, 48, and 96 sides about a circle.

Stomachion

Heiberg recovered only the opening sentences though other references (Dijksterhuis, 1987, pp. 408–412) to this text have become known as the *loculus Archimedius* (Archimedes' box), a kind of game or puzzle consisting of fourteen pieces of ivory in various triangular shapes cut from a square. It is assumed that these pieces were to be reassembled into other forms, e.g., a ship, sword, or tree. After much thought, Netz concluded that Archimedes asked the modern combinatorial question, "In how many ways can you put the 14 pieces together to form a square?" Answer: 17,152. Netz headed a team of Persi Diaconis, Susan Holmes, Ronald Graham, Fan Chung, and William Cutler who systematically counted all possibilities and then validated their calculation with a computer program.

Method of Mechanical Theorems

The *Method* holds a very special niche among pure mathematicians and classicists. The book opens with a letter sent by Archimedes in Sicily to Eratosthenes in Alexandria. For decades mathematicians have savored its closing:

> I am convinced that it (the method) will prove very useful for mathematicians; in fact, I presume there will be some among the present as well as future generations who by means of the method here explained, will be enabled to find other theorems which have not yet fallen to our share.
>
> *—(Dijksterhuis, pp. 313–315, et al)*

This has to be one of the more provocative statements ever written by a great mathematician. Clearly Heiberg, Heath, and dozens of other scholars were and are intrigued. Wilbur Knorr wrote, "It is…extraordinary that fully eight decades later there is still no adequate translation of this work into English; for the version by Heath is based on Heiberg's text." Alas, a scholar cannot translate that which cannot be seen; thus, the importance of new imaging techniques for the current quest to translate the palimpsest. While presenting meticulous details about other propositions, Dijksterhuis basically skips Propositions 14 and 15 (pp. 332–335) due to gaps in the visible evidence.

In particular, the interpretation of methods in Proposition 14 and Proposition 15 is at stake. Be reminded that the shoulders of giants stood on by Archimedes surely included the following:

1. From Eudoxus (408-355 BC) he knew the concept of a "method of exhaustion".

2. From Hippocrates (460-380 BC) he knew the special case for finding the quadrature of the circle (the area of a curvilinear lune equals the area of one-half of a 45° -45° -90° triangle inscribed in a semicircle).

3. From Euclid (323-285 BC) he surely had learned that in two similar solids (a) the lateral and surface areas have the same ratio as the square of any pair of corresponding segments; (b) the

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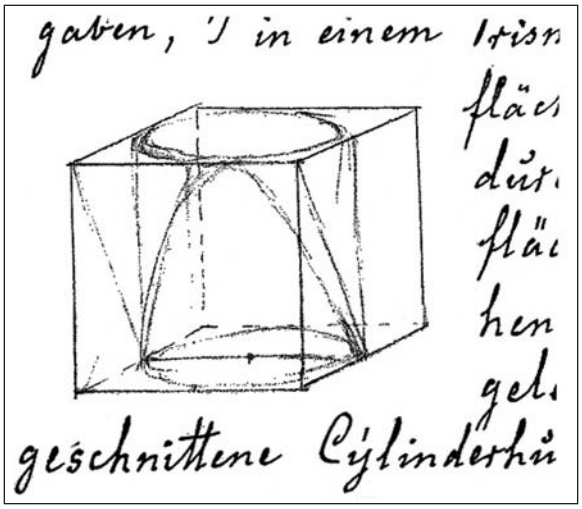
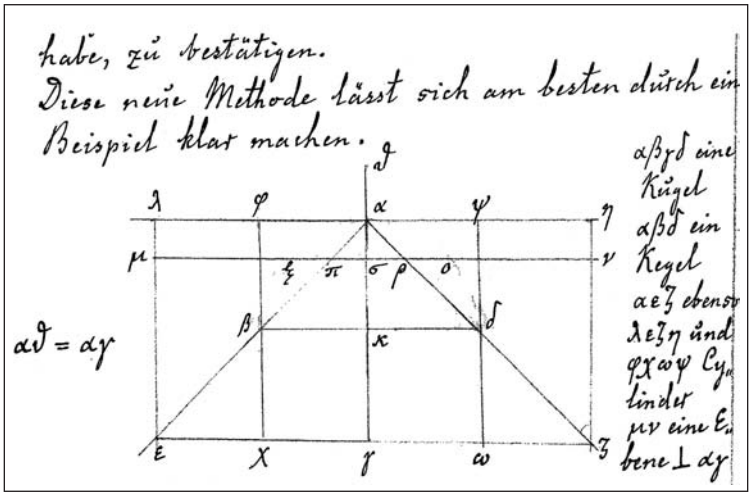


The geometrical illustrations in the original palimpsest were drawn with a finer stylus than the pen used for text. In several instances Heiberg and Heath were forced to guess at their reconstruction. This illustration of the "Cylinderhüf" or "cylinder hoof" was drawn by Heiberg (Heiberg, 1908, p. 7).



Heiberg's illustration of Archimedes' signature investigations of related volumes of cones, spheres, and cylinders (Heiberg, 1908, p. 5).

volumes have the same ratio as the cube of any pair of corresponding segments.

4. Archimedes experimentally determined that the areas of cross sections of two bodies have an intimate relationship: the length of the lever arm times the area of one cross section equals a constant times the area of a cross section of another solid.

In translating the letter from Archimedes to Eratosthenes, Heiberg used the German verb "knüpfen" or "tying together" for what Archimedes hoped to achieve with their collaborative knowledge of mathematical truths in the *Method*.

In Proposition 14 Archimedes deals with a proof introduced earlier regarding the volume of a cylinder "hoof"; thus, he deals with cross sections of a paraboloid to conclude that the volume of the "hoof" is two-thirds of that of the prism and consequently one-sixth of that of the cube circumscribed about the cylinder. His method now avoids the concept of equilibrium, but continues with visualizing a solid as the sum of its parallel intersections. To quote Dijkersterhuis, "This proof therefore does not yet satisfy the requirement of exactness."

Proposition 15 was "lost" one century ago, but appeared to Heath to be the same posited in Proposition 14, but with a different method to drawing the same conclusion. "As however the two propositions are separately stated, there is no doubt that Archimedes' proofs of them were distinct." (Well, maybe; the gaps are enormous.) Dijksterhuis asserts "the concept of volume as being the sum of the areas of parallel intersections is abandoned" and then takes a giant scholarly leap in publishing "the method of the indirect limiting process is applied." He inserts his personal proof by contradiction. Continuing on Proposition 15, he refers readers to Heath's reconstruction (p. 48) but fails to elaborate. Heath writes, "There is no doubt that Archimedes proceeded to, and completed, the rigorous geometrical proof by the method of exhaustion" (p. 51).

Did Archimedes really grasp integration as we think of it today? Several points are to be made. In London, Heath, nearing completion of his monumental work on Euclid, perused the investigations of his colleagues' research from the Middle East to write, "One of the two geometrical proofs is lost, but fragments of the other are contained in the manuscript which are sufficient to show that the method was the orthodox *method* of exhaustion in the form in which Archimedes applies it elsewhere, and to enable the proof to be *reconstructed*." A purist would remark that a reconstruction is not a verbatim or literal translation. The missing portions, the lacunae, are important.

The four premises known to Archimedes have been refined over their 2,000 year history. To the method of exhaustion have been added modern concepts of limit, infinity, and convergence. Today we speak of the center of gravity and calculate the moment of a system about an axis. Cross sections of thickness dx must be parallel to one another and perpendicular to an axis. Equations and notation are far less cumbersome than doing mathematics expressed in literal sentences. Heath informally observed, the "dx" thickness of perpendicular cross sections cancels on both sides of Archimedes' expression of equilibrium.

Heiberg summarized the evolution of Archimedes with different emphases: "Even stranger is the boldness with which the assumption operated that

(1) a plane is filled with lines and that (2) a body consists of or is filled with circles. This is, in fact, our infinity-based calculus, which Archimedes already used as a method while the meaning of infinity in Greek mathematics was usually strongly rejected as exactly not comprehensible and therefore dangerous. That is why Archimedes emphasizes that these 'Raisonnements' cannot be proven and instead only yield likely suspicions that require a strict form of exhaustion, the geometric proof" (Heiberg, 1908).

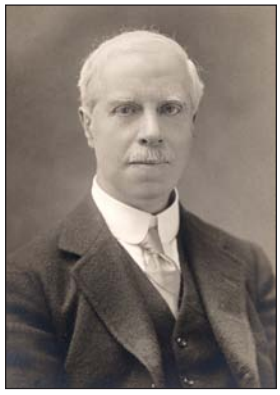
C. H. Edwards writes "While it is true that Archimedes' work ultimately gave birth to the calculus, three indispensable ingredients of the calculus are missing in his method" (Edwards, 1979). Briefly, (1) the explicit introduction of limit concepts, (2) a computational algorithm for the calculation of areas and volumes, and (3) a recognition of the inverse relationship between area and tangent problems. Any instructor teaching calculus can recognize the symbiotic relationship between Archimedes and chapters we routinely teach today. Yet there is an incompleteness to the thoughts of Archimedes that will be debated even after the palimpsest project finishes its imaging and translation.

2008 Technology

The state of the art for photography was not sufficiently developed in 1906 to enhance the pale, stone-scrubbed underscripted ink, though Heiberg translated approximately 80 important mathematical illustrations that could not be seen. Of the 177[1] leaves noted by Heiberg, Heath later reported 29 leaves that were destitute of any trace of underscript, and 9 pages that had been "hopelessly washed off; on a few more leaves, only a few words can be made out; and again some 14 leaves have old writing upon them in a different hand and with no division into columns."

Both Heiberg and Heath were captives of the technology of their generation. Imaging is in a far more advanced state today. Mathematicians and paleographers are intrigued by the wish to see the missing late twelfth or early thirteenth century illustrations and proof—not their reconstruction. We have no need to question the work of the great scholars at the turn of the last century. But today we have far more imaging options. Powerful optical spectroscopic methods can be employed along with digital enhancement techniques to reveal features in the palimpsest that hitherto have not been legible. (The fluorescence and other spectroscopic properties of pre-Columbian inks used by North American Indians are well known.) Strikingly characteristic emission spectra of different inks observed under ultraviolet excitation can be exploited, but care must be exercised in such experiments, since UV light has the potential to bleach the delicate traces of ink in the thousand-year-old manuscript. Recall the darkened libraries and art museums prescribed by conservators.

The most recent imaging technique has been to scan the palimpsest using rapidly emitted, finely focused x-ray beams that excite fluorescence in the latent inks. Thus the metal atoms in ancient inks come alive. Related spectroscopic methods have long been used by physicists and chemists, especially at the Department of Energy's Stanford Linear Accelerator Center (SLAC), to determine the precise separations of atoms in biological and other complex molecular structures. The intensity of the fluorescence in key regions can be amplified to produce clear images if any trace of the ink remains in previously hidden writings. (Mathematicians will enjoy discussion with colleagues in the physical and biological sciences concerning the relative merits of steady-state fluorescence and the newer time-resolved absorption-emission methods that employ femtosecond and picosecond x-ray pulses.)



Thomas Little Heath.
Photo courtesy of the Royal Society London.

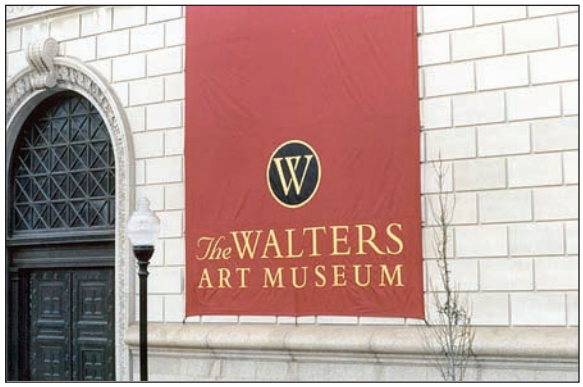
We wish to see the text and geometrical illustrations from *The Method* that may or may not validate our fondest wish that Archimedes did, in fact, have the thoughts required for modern techniques of finding volumes by integral calculus. We want to see and to read all of the world's oldest copy of Archimedes' method.

Heath

Heiberg's announcement of finding the palimpsest (1907) and his subsequent publications appearing in German must have come as a great surprise to Heath. He immediately set about to update *The Works of Archimedes* (1897) with a supplement, *The Method of Archimedes Recently Discovered by Heiberg* (1912). In English, this publication found in many university libraries has become an indispensable source for scholars of Propositions 14 and 15.

Heath was truly in his element when writing about Heiberg's translation. Like Newton, Heath was born in Lincolnshire and educated at Trinity College, Cambridge. Following his "first class" on the tripos, he went up to London to become a civil servant in the Treasury. He was quick, accurate, neat, and thorough in all written work. His honesty was never questioned. However, the

[1] *In examining the palimpsest in 1999 Nigel Wilson counted 178 leaves. In 1906 Heiberg made 65 photos, some of a single page, others of an opening.*



Photograph courtesy of the author.

The Palimpsest is now under the watchful care of the Walters Art Museum in Baltimore.

very qualities that would merge into his becoming one of the world's greatest classical scholars would also lead to his demise in the office place. Victorian to the hilt, Heath opposed women in the office, telephones, and oral briefings; moreover, he cut budgets. Heath was at ease with the stuffy, candle-saving formality of the old Treasury prior to World War I. But modernization reforms under Lloyd George resulted in his being pushed aside. Those who cut budgets are seldom popular. Possibly his pedantic stiffness was unsettling to those less dedicated in their work.

Heath was one of a small number of British civil servants who managed to use leisure time to make a major impact on scholarship. Thus, he achieved in two simultaneous careers, one as a scholar and the other as a government employee. While working from 1884 until his retirement at the age of 65 he published major treatises on Diophantus (1885), Apollonius (1896), his original Archimedes (1897), and seven other publications. His style was to use modern mathematical notation while faithfully translating the literal expositions from difficult Greek and Medieval Latin. He rendered the text to be readily understood by all contemporary mathematicians. His polished, meticulous prose with modern mathematical notation culminated in the monumental three-volume *non pareil* edition of Euclid's *Elements* (1908). Though published one century ago, his work on Euclid remains in print and is in virtually every university library. In particular, his treatment of rational and irrational magnitudes in Book X is considered a masterpiece. Heath became the indispensable gatekeeper for opening the works of ancient Greek mathematics to modern students. Readers of the *Notices* also know *A History of Greek Mathematics* (1921) as the definitive two-volume work on the subject.

Heath had a passion for trains and rock climbing. He was an unerring sight-reading pianist. His wife, Lady Ada Heath, wrote "Music served as a solvent of difficulties which arose in the writing of his books on Greek Mathematics. He would wander over to the piano and play one or more of Bach's '48'. Watching him, it was obvious at what point his difficulty was cleared up, when he would go back to his desk and continue his writing." He even published Euclid in the original Greek (1920), hoping his notes would fascinate schoolboys into doing more proofs.

Heiberg and Heath after Constantinople

Heiberg was awarded two additional honorary doctorates, one from Leipzig (1909) and one in medicine from Berlin (1910). Throughout his career he had been both a prolific author and an editor, but largely turned to Greek medicine in his final years. He also served as rector of the University of Copenhagen (1915–1916). As a shy young man, few would have predicted he would become a gregarious social leader, much loved by his students and colleagues. While his friends were strongly religious, he attempted to remove both Oriental and mystic influences in his writings. He had little interest in Roman contributions. Outside of antiquity, he admired Kierkegård. Travelers to Copenhagen today may visit his grave in Holmens and see his portrait in the restored Renaissance-style Frederiksborg Castle on a lake near Hillerød.

Like Heiberg, honors filled Heath's career. Undoubtedly his thoroughness in translating Euclid led to his being knighted (K.C.B., 1909; K.C.V.O., 1916) and named a Fellow of the Royal Society (1912). He joined Heiberg in being awarded an honorary degree from the University of Oxford (1913). His college (Trinity) at Cambridge named him an honorary fellow (1920). His professional service included being on the council of the Royal Society and serving as president of the Mathematical Association. American readers will find it unusual that his wealth at death (£18.427 9s 2d) in 1940 is published information (resworn probate, April 25, 1940, *CGPLA Eng. & Wales*).

Archimedes and the Palimpsest at the Year 2008

Archimedes can become addictive. Sherman Stein (p. ix) wryly notes that each time he teaches the history of mathematics he puts more time on Archimedes. Finally on his fifth time, seven of his twenty lectures were devoted to Archimedes, while Newton and Leibniz received hasty treatment. He also asserts Heath and Dijksterhuis are hard to read, while Heiberg is available only in German or translation. Chris Rorres has shared his lifelong passion for collecting Archimedean materials and was one of the very first to launch a mathematics website (1995). See `http://www.mcs.drexel.edu/~crorres/Archimedes/contents.html`.

Reviel Netz remarks, "I am always humbled by Heiberg" but has the reservation that when Heiberg inserted bracketed passages that are not clearly Achimedes' own, Heiberg might have been too fast in his judgment. By modern standards, we know

not to second guess an ancient translator or author too quickly. Yet, a scholar's opinion has value.

Following the Christie's auction, the current owner placed the "lost" palimpsest in the hands of the Walters Art Museum in Baltimore; William Noel is heading the project of restoration, imaging, and translation. Both the seller and the buyer, exchanging US$2 million "under the hammer", strongly wish to remain anonymous. This is highly understandable—indeed, as a priest who leads pilgrimages to the Patriarchate in Jerusalem and to Istanbul remarked to this author, "The palimpsest of Archimedes is to the Greek Orthodox Church what the Elgin Marbles are to the Greek government." Both the *New York Times* and the *KATHIMERINI* of Athens report the owner has pledged not to limit access to the ancient manuscript.

Concluding Remarks

In 2008, one century after publication, Heath's edition of Euclid's *Elements* is still being printed and sold throughout the world. Only a handful of mathematics publications can make this claim. A visitor to the National Portrait Gallery in London can see Heath's photograph, along with DeMorgan and Boole, but not Hardy and Littlewood. Without Heath's translation, Heiberg would be largely unknown in a world now dominated by English. What is more, we should not forget to pay tribute to Heiberg. Were it not for his determined efforts to find grant money, to make difficult journeys across Europe, and to publish demanding scholarly work, we as mathematicians would be much the poorer. It is altogether fitting that we pay tribute to both Heiberg and Heath on the centennial of their landmark work.

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http://archimedespalimpsest.org/

http://www.thewalters.org/

http://www.slac.stanford.edu/gen/com/slac_pr.html

WHAT IS...

Outer Space?

Karen Vogtmann

To investigate the properties of a group G, it is often useful to realize G as a group of symmetries of some geometric object. For example, the classical modular group $PSL(2,\mathbb{Z})$ can be thought of as a group of isometries of the upper half-plane $\{(x,y) \in \mathbb{R}^2 | \, y > 0\}$ equipped with the hyperbolic metric $ds^2 = (dx^2 + dy^2)/y^2$. The study of $PSL(2,\mathbb{Z})$ and its subgroups via this action has occupied legions of mathematicians for well over a century.

We are interested here in the (outer) automorphism group of a finitely-generated free group. Although free groups are the simplest and most fundamental class of infinite groups, their automorphism groups are remarkably complex, and many natural questions about them remain unanswered. We will describe a geometric object $\mathcal{O}_n$ known as *Outer space*, which was introduced in [2] to study $Out(F_n)$.

The abelianization map $F_n \to \mathbb{Z}^n$ induces a map $Out(F_n) \to GL(n,\mathbb{Z})$, which is an isomorphism for $n = 2$. Thus the upper half plane used to study $PSL(2,\mathbb{Z})$ can serve equally well for $Out(F_2)$. For $n > 2$ the map to $GL(n,\mathbb{Z})$ is surjective but has a large kernel, so the action of $Out(F_n)$ on the higher-dimensional homogeneous space $SL(n,\mathbb{R})/SO(n,\mathbb{R})$ is not *proper*... stabilizers of points are infinite and difficult to understand. This makes the homogeneous space unsuitable for studying $Out(F_n)$, and something new is needed.

$PSL(2,\mathbb{Z})$ can also be interpreted as the mapping class group of a torus, and the upper half-plane as the Teichmüller space of the torus. This shift in viewpoint motivates the construction we will give here of Outer space. In general, the mapping class group of a closed surface S is the group of isotopy classes of homeomorphisms of S. (Recall that two homeomorphisms are *isotopic* if one can be deformed to the other through a continuous family of homeomorphisms.) One way to describe a point in the Teichmüller space of S is as a pair (X,g), where X is a surface equipped with a metric of constant negative curvature, and $g\colon S \to X$ is a homeomorphism, called the *marking*, which is well-defined up to isotopy. From this point of view, the mapping class group (which can be identified with $Out(\pi_1(S))$) acts on (X,g) by composing the marking with a homeomorphism of S—the hyperbolic metric on X does not change. By deforming the metric on X, on the other hand, we obtain a neighborhood of the point (X,g) in Teichmüller space.

To get a space on which $Out(F_n)$ acts, we imitate the above construction of Teichmüller space, replacing S by a graph R with one vertex and n edges (a *rose with n petals*). However, we no longer insist that the marking g be a homeomorphism; instead we require only that g be a homotopy equivalence, and we take its target X to be a finite graph whose edges are isometric to intervals in $\mathbb{R}$. Thus a point in $\mathcal{O}_n$ is a pair (X,g), where X is a finite metric graph and $g\colon R \to X$ is a homotopy equivalence. Two pairs (X,g) and (X',g') are equivalent if X and X' are isometric and g is homotopic to g' under some isometry. In order to make $\mathcal{O}_n$ finite-dimensional, we also assume that the graphs X are connected and have no vertices of valence one or two. Finally, it is usually convenient to normalize by assuming the sum of the lengths of the edges is equal to one.

The mapping class group acts on Teichmüller space by changing the marking, and the analogous statement is true here: an element of $Out(F_n)$,

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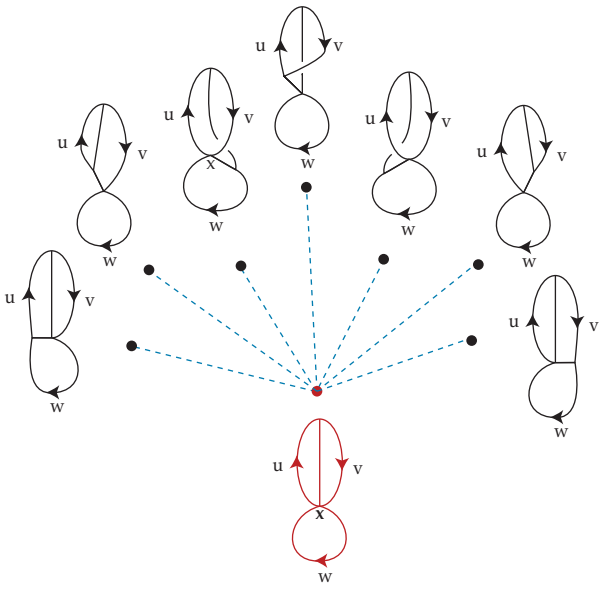

Figure 1: Marked graphs that are close in Outer space.

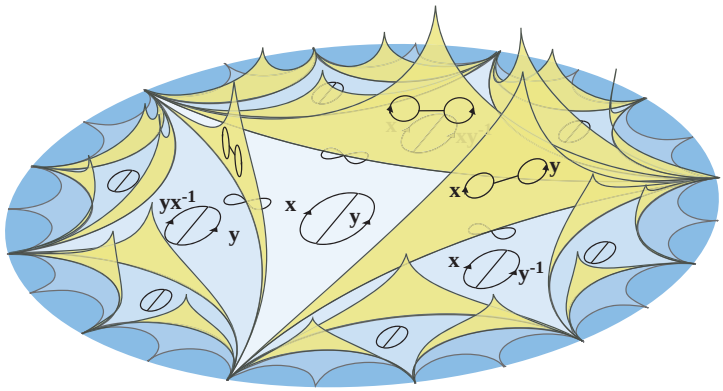

Figure 2: Outer space in rank 2.

represented by a homotopy equivalence of R, acts on Outer space by changing only the marking, not the metric graph. A major difference from Teichmüller space appears when one looks closely at a neighborhood of a point. Teichmüller space is a manifold. In Outer space points arbitrarily close to a given point (X, g) may be of the form (Y, h) with Y not homeomorphic to X. An example is shown in Figure 1, where several marked graphs near the red graph are obtained by folding pairs of edges incident to the vertex x together for a small distance. In general there are many different possible foldings, and this translates to the fact that there is no Euclidean coordinate system that describes all nearby points, i.e., Outer space is not a manifold.

Outer space is not too wild, however…it does have the structure of a locally finite cell complex, and it is a theorem that Outer space is contractible. It also has the structure of a union of open simplices, each obtained by varying the edge-lengths of a given marked graph (X, g). For $n = 2$ these simplices can have dimension 1 or 2, but not dimension 0, so Outer space is a union of open triangles identified along open edges (Figure 2).

The stabilizer of a point (X, g) under the action of $Out(F_n)$ is isomorphic to the group of isometries of the graph X. In particular, it is a finite group, so the action is proper. Therefore Outer space serves as an appropriate analog of the homogeneous space used to study a lattice in a semisimple Lie group, or of the Teichmüller space used to study the mapping class group of a surface.

The analogies with lattices and with mapping class groups have turned out to be quite strong. For example, it has been shown that $Out(F_n)$ shares many cohomological properties, basic subgroup structure, and many rigidity properties with these classes of groups. The proofs of these facts are frequently inspired by proofs in the analogous settings and use the action of $Out(F_n)$ on Outer space. However, the details are often of a completely different nature and can vary dramatically in difficulty, occasionally being easier for $Out(F_n)$ but more often easier in at least one of the other settings.

Perhaps the most extensive use of Outer space to date has been for computing algebraic invariants of $Out(F_n)$ such as cohomology and Euler characteristic. Appropriate variations, subspaces, quotient spaces, and completions of Outer space are also used. For example, the fact that $Out(F_n)$ acts with finite stabilizers on $\mathcal{O}_n$ implies that a finite-index, torsion-free subgroup Γ acts freely. Therefore the cohomology of Γ is equal to the cohomology of the quotient $\mathcal{O}_n/\Gamma$ and vanishes above the dimension of $\mathcal{O}_n$. In fact a stronger statement is true: the cohomology must also vanish in dimensions below the dimension of $\mathcal{O}_n$. In order to find the best bound on this vanishing (called the *virtual cohomological dimension* of $Out(F_n)$), we consider the so-called *spine* of Outer space. This is an invariant subspace K_n of much lower dimension than $\mathcal{O}_n$ that is a deformation retract of the whole space. The dimension of K_n gives a new upper bound for the virtual cohomological dimension, and this upper bound agrees with a lower bound given by the rank of a free abelian subgroup of $Out(F_n)$.

Further uses for the spine of Outer space come from the observation that the quotient $K_n/Out(F_n)$ is compact. As a result one can show, for example, that the cohomology of $Out(F_n)$ is finitely-generated in all dimensions and that there are only finitely many conjugacy classes of finite subgroups. The spine is a simplicial complex on which

$Out(F_n)$ acts by permuting the simplices, and in fact it was shown by Bridson and Vogtmann that $Out(F_n)$ is isomorphic to its full group of simplicial automorphisms. Thus the the spine intrinsically contains all possible information about the group!

There are many recent papers on $Out(F_n)$ and Outer space, including work on compactifications, metrics and geodesics, dynamics of the action, embeddings and fibrations, and connections to operads and symplectic representation theory. The interested reader is referred to the three survey articles [1], [3], and [4] for further history and for discussion of some of the recent developments.

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Outer Space for $n = 2$

Let x and y be generators of the free group F. Then $x \mapsto [1,0]$, $y \mapsto [0,1]$ gives rise to an isomorphism of the maximal abelian quotient of F with $\mathbb{Z}^2$. The group $\mathrm{Out}(F)$ of outer automorphisms of F therefore maps into $\mathrm{GL}_2(\mathbb{Z})$. Define automorphisms of F:

$$\alpha_x : x \mapsto x^{-1}, y \mapsto y; \quad \alpha_y : x \mapsto x, y \mapsto y^{-1}$$

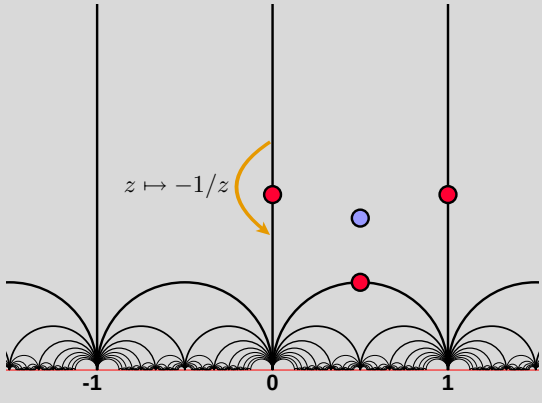
$$\beta_{x,y} : x \mapsto xy, y \mapsto y; \quad \beta_{y,x} : x \mapsto x, y \mapsto xy$$

Their images generate $\mathrm{GL}_2(\mathbb{Z})$. The inner automorphisms of F are in the kernel, and Nielsen showed in 1917 that in fact the map induces an isomorphism of $\mathrm{Out}(F)$ with $\mathrm{GL}_2(\mathbb{Z})$. As Karen Vogtmann's Figure 2 suggests, the structure of Outer space is compatible with the classical action of $\mathrm{GL}_2(\mathbb{Z})$ on the upper half plane (or, in her figure, the equivalent action on the interior of the unit disk). This is explained in more detail in the article by Culler and herself, found in her reference list.

Outer space in this case is assembled from simplices, each one parametrized by a homeomorphism class of graph G with $\pi_1(G) = F$ satisfying some non-degeneracy condition, together with extra data. The non-degeneracy means that there are three topological types of graphs involved:

The first type can be retracted to the second by collapsing the connecting edge. In terms of Outer space, this means that the triangles associated to graphs of this type can be retracted to the edges associated to the second. The second type corresponds to one-dimensional edges in Outer space, and the third type to triangles with these edges as boundary. The triangulation of Outer space parametrized by the two last types is essentially the triangulation of the upper half plane associated to the Farey series. The points indicated below correspond to symmetrical choices of lengths.

—Bill Casselman



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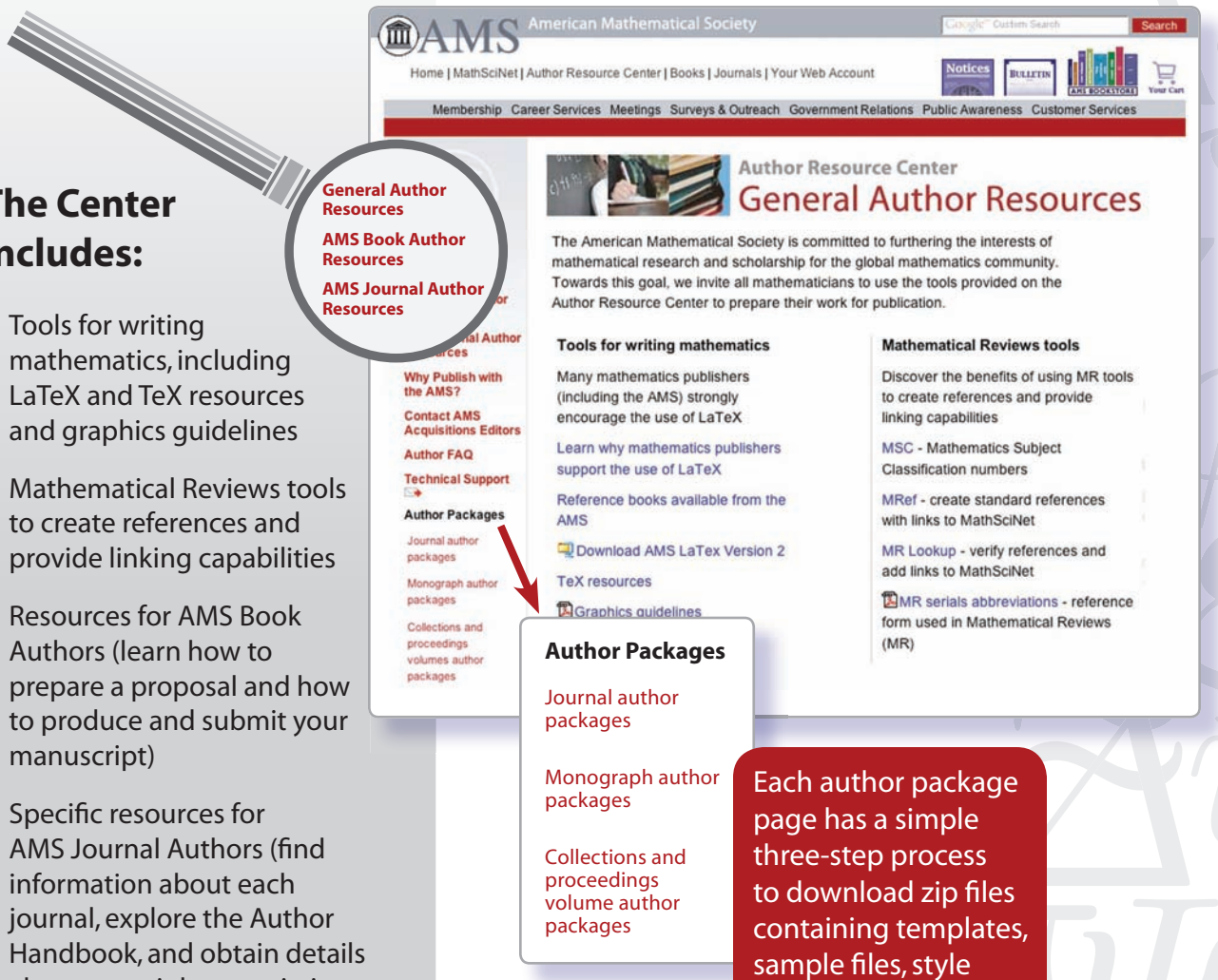

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Irreligion

Reviewed by Olle Häggström

Irreligion: A Mathematician Explains Why the Arguments for God Just Don't Add Up
John Allen Paulos
Hill and Wang, 2007
US$20.00, 176 pages
ISBN-13 978-0809059195

John Allen Paulos' latest book *Irreligion: A Mathematician Explains Why the Arguments for God Just Don't Add Up* [11], contains rather little mathematics. Yet the title is not terribly misleading: the book's style would, in case we didn't know that the author is a mathematician, hint strongly in that direction. Paulos' basic strategy for analysis of arguments bears clear signs of a mathematical mindset: he strips the arguments to their bare bones and divides them into small steps, so that the strength and weakness of each of the steps can be readily evaluated. The application of this strategy to a wide variety of arguments for God's existence constitutes the main content of his book.

Here is Paulos' bare-bones recounting of the ontological argument of Anselm, the well-known eleventh century Archbishop of Canterbury (pages 38–39):

1. God is a being than which nothing greater can even be conceived.
2. We understand the notion of God as well as the notion of God's really existing.
3. Let's also tentatively assume God doesn't exist.
4. If we understand the notion of a positive being and that being really exists, then this being is greater than it would have been if we only understood the notion of it.
5. From these assumptions, we conclude that if God did not exist, we could conceive of a being greater than God (a being just like God, but really existing). This is a contradiction since God is a being than which nothing greater can be conceived.
6. Thus Assumption 3 is refuted and God exists.

This argument is of considerable historical interest and therefore deserves analysis. It seems unlikely, however, that many people today attach great significance to it in their choice to believe or not to believe in God. Sampling a believer at random, we are presumably much more likely to find the following "argument from emptiness", as Paulos calls it, to be influential (page 76):

1. People wonder if this is all there is and ask, "What will any of my concerns matter in one thousand years?"
2. They find this prospect so depressing that they decide there must be something more.
3. This something more they call God.
4. Therefore God exists.

(Note how these examples illustrate a recurrent theme in the book—and in much of theological discussion more generally—namely, the potential for confusion arising from flexibility and vagueness in how to define "God".) Typically, once the argument is spelled out in this manner, finding one or more fatal flaws is a relatively simple matter, which the author executes with clarity and wit; I leave the cases of the two arguments above as an exercise for the reader.

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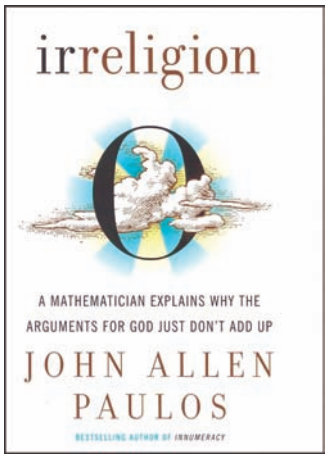

I like Paulos' method, which in most cases makes it evident not only that the stripped-down versions of the arguments fail, but also that no refinement or elaboration will save them from their central shortcomings. Not everyone agrees, however. In a negative review of *Irreligion* in the *New York Times*, Jim Holt [7] dismisses Paulos as attacking straw men and failing to consider the much more sophisticated arguments embraced by contemporary theologians and philosophers of religion. H. Allen Orr, in the *New York Review of Books* [9], files the same complaint against Richard Dawkins' best-selling *The God Delusion* [2]. Neither Holt nor Orr provide any specific references, however, so readers are left to search the theological literature on their own. But are the alleged so-much-better arguments anywhere to be found? Frankly, I suspect that Holt and Orr simply mistake verbosity for profundity.

In current public debate, the loudest case for God's existence is made by the intelligent design lobby, claiming that Darwinian evolution cannot account for advanced life forms such as ourselves, which must therefore be the work of an intelligent designer. Leading intelligent design proponent William Dembski (who actually has a Ph.D. in mathematics) specializes, in books like *The Design Inference* [3] and *No Free Lunch* [4], in dressing up such arguments in fancy-looking mathematics. The mathematics makes it difficult for the general public, and even for most biologists, to see through his arguments. There is therefore a useful role to be played by mathematicians in clearing up Dembski's smokescreens; see [6] and [8] for a couple of recent contributions. Paulos, however, refrains from taking up this task and from discussing evolutionary biology in any detail whatsoever. Instead, he settles for the following ironic observation. Christian right-wing commentators, who claim that complex well-functioning biological structures cannot come about without the aid of an intelligent designer, rarely express doubt over whether a complex and well-functioning economy can come about without the aid of a central planning bureau.

Irreligion clearly alludes to the title of the book that twenty years ago made Paulos' breakthrough as a public intellectual: *Innumeracy* [10]. The two books have a lot in common, for instance in the generally debunking character, which makes for good entertainment but also carries a risk that the tone becomes patronizing. Paulos manages this balance very well in *Innumeracy*, but not quite as well in *Irreligion*. Among readers of *Irreligion* there will presumably not be many who consider themselves believers, but those who do may well be offended by some rather unnecessary choices of examples, such as when the difficulty of proving that God does *not* exist is compared to the hopeless task of conclusively ruling out that, somewhere in the universe, there exists "a dog who speaks perfect English out of its rear end".

The main reason, however, that *Irreligion* is a less fully satisfying book than *Innumeracy* is the following. The debunking in *Innumeracy* of poor quantitative thinking and faulty mathematics is followed by inspiring discussions about how to think correctly about numbers, probabilities, and quantitative estimates. *Irreligion* contains very little in terms of such positive counterparts. Once the arguments for God's existence are demolished, Paulos finds nothing in the ruins worth building a better paradigm on.

One final comment on *Irreligion*: Paulos' mission is not primarily directed against the idea that there might exist a God, but rather against sloppy reasoning. It might therefore have been a good idea to dissect, among all the failed arguments for God's existence, also one or two such arguments for God's *non-existence*. Paulos offers nothing of this kind beyond paying lip service to the impossibility of proving God's non-existence.[1] A good choice would have been the widely quoted non-existence argument that Dawkins puts forth in his aforementioned book. I will end this review by briefly making up for this omission.

In the fourth chapter of *The God Delusion*, with the title "Why there almost certainly is no God", Dawkins defends an argument for God's non-existence that is hardly any better than the existence arguments that he rightly dismisses in an earlier chapter. His starting point is a favorite principle among intelligent design proponents such as Dembski: A blacksmith can manufacture a horseshoe but not vice versa, and more generally complex objects cannot be the product of simpler ones but only of more complex ones; hence we must be designed by some being more complex than ourselves, whom we might as well call God.

[1] *This is done in connection with the flatulent dog example quoted above, but the argument is not particularly convincing. While dogs tend to be located in physical space-time, God doesn't (according to many defenders of the God idea). The usual asymmetry between proving $\exists$-statements and proving $\forall$-statements applies mainly to objects with a location in space-time, while for other kinds of objects, such as integer quadruples (x, y, z, n) with $n \geq 3$ and $x^n + y^n = z^n$, $\forall$-statements are not always beyond provability. Why should God be more like dogs than like integer quadruples in this respect?*

A standard objection to this argument is that it doesn't explain much, because this God must then be the product of an even greater God, and so on *ad infinitum*. Dawkins combines this objection with another favorite argument among intelligent design proponents, namely the shaky[2] claim that greater complexity implies smaller probability. Together, these arguments imply that we are the product of a God who is less probable than we are, and who is the work of an even less probable God, and so on. Taking limits in this hierarchy of Gods, Dawkins concludes that the God hypothesis has probability 0.

Let us, for the sake of the argument, be generous to Dawkins and accept both the principle of greater complexity implying smaller probability, and the lemma that an infinite decreasing sequence of probabilities must approach 0. What, then, does Dawkins' argument achieve? It does raise serious doubts about the blacksmith-horseshoe principle (just in case we hadn't dismissed that one already in view of the multitude of counterexamples provided by evolutionary biology). But does it rule out the existence of God? Hardly.

For instance, we may reject the blacksmith-horseshoe principle and still insist on a God who created us but who came about according to some "bottom-up" process such as Darwinian evolution in a different universe. Oddly enough, Dawkins admits this possibility ([2], p. 156), but says that he doesn't "believe for a moment" in such a God. As a harsh but hardly unfair summary of Dawkins' argument, I therefore propose "I don't believe for a moment that Gods of a certain kind exist [...] so we may conclude that there almost certainly is no God".

It is worth noting in this context that a God of the kind that Dawkins' argument doesn't address has been suggested by philosopher Nick Bostrom [1], who reasons as follows. If we (humanity) don't destroy ourselves, then we will soon have access to computing resources of absolutely astounding proportions. Some of those resources will be used by historians carrying out stupendously detailed simulations of (variations of) those critical decades or centuries leading up to the great technological leap. Thus, for every human living in 2008 there are millions who believe themselves to live in 2008 but who actually live inside a computer simulation run in 2250 or so. (Those who have seen *The Matrix* will recognize this scenario.) Hence, we probably live in such a simulation, and the historian running it qualifies for most of the usual requirements for the title "God": he created us, and he can at any time interrupt the simulation and make suitable changes (miracles) to it. And if we accept that he came about via evolution by natural selection, then he falls squarely in the category of Gods about whom Dawkins' argument has nothing to offer.

Bostrom's argument rests on several unproven hypotheses, including the so-called computational theory of mind (see, e.g., [5]), so we are in no way forced to accept it. But I must admit to finding it more interesting than most of the more conventional arguments for God's existence treated by Paulos.

[2] *I say "shaky" rather than "false", because to say that a statement is false requires that it makes sense, which in turn requires that all the notions in the statement have been defined; the latter requirement is not fulfilled in Dawkins' treatment.*

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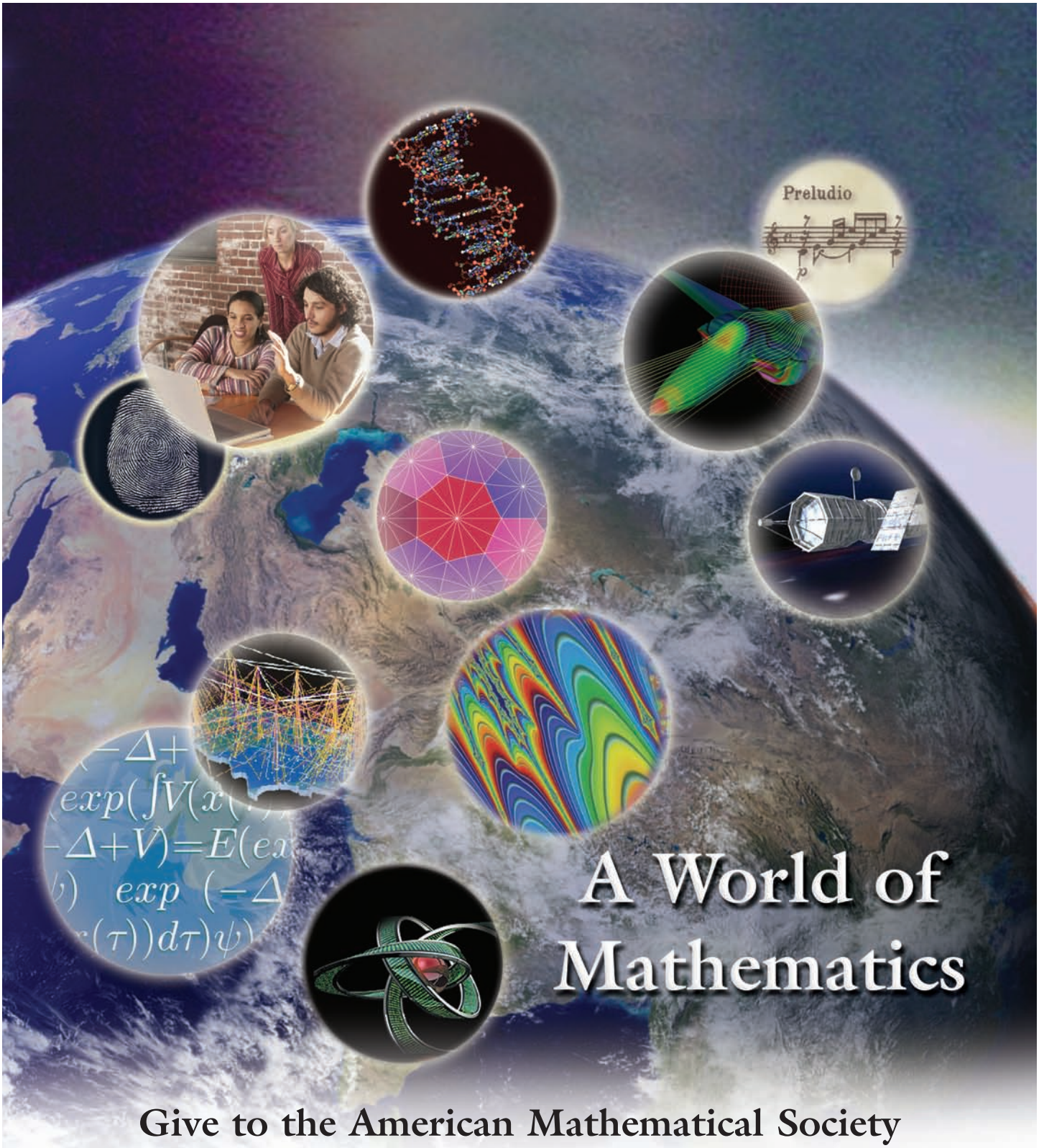

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08/04

In Puris Naturalibus

Reviewed by Lewis Pyenson

Pursuit of Genius: Flexner, Einstein, and the Early Faculty at the Institute for Advanced Study
Steve Batterson
A K Peters, June 2006
US$39.00, xii + 301 pages
ISBN-13: 978-1568812595

For people with a career at a university lacking a faculty club, the Institute for Advanced Study at Princeton seems like the land of Cockaigne. Scholars and scientists paid to think. A physicist freed from lecturing to legions of pre-medical students; a historian who need not continually explain the origins of the First World War to future tax accountants and divorce lawyers. Subsidized lunch, civilized tea. The institute is a place where one can imagine crossing the path of Hesse's Joseph Knecht or Marlowe's John Faustus. Or one might watch, as Leopold Infeld recalls in his autobiography *Quest*, Tullio Levi-Civita and Albert Einstein discussing gravitational waves: "the calm, impressive Einstein and the small, thin, broadly gesticulating Levi-Civita as they pointed out formulae on the blackboard and talked in a language which they thought to be English", with "Einstein pulling up his baggy trousers every few seconds." By focusing on Abraham Flexner, the central actor in establishing the institute, *Pursuit of Genius* recounts how the institute came to enjoy its reputation.

Bankrolled by the Bamberger-Fuld department-store fortune in the early 1930s, Flexner began with the notion of an elite graduate student university, a combination of the Johns Hopkins University and the Rockefeller Institute for Medical Research. Flexner, a man of wide academic experience and thin academic accomplishment, proceeded with tunnel vision. A few minutes with the academic register *Minerva* would have revealed a wide range of Western European models, among them the

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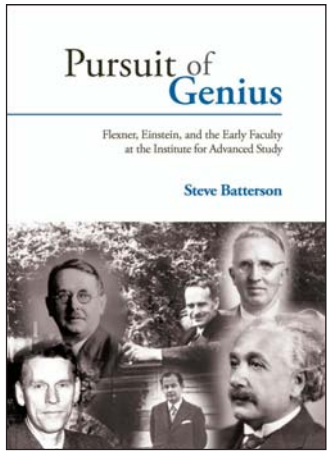

Collège de France in Paris, the Royal Institution in London, the Kaiser-Wilhelm Gesellschaft in Berlin, the Residencia de Estudiantes in Madrid, along with the Solvay institutes in Brussels and the Nobel Institution in Stockholm. Intellectuals, notably Paul Otlet, were planning for a "World City" of academic and scientific activity. In the United States, there was, most obviously, the Carnegie Institution of Washington, with groups ranging from astrophysics and genetics to history and archaeology. Although Flexner later borrowed eclectically, none of these institutions or initiatives figured in his initial plans.

Louis Bamberger imagined, initially, a location in Newark, the place of his home and fortune, and his thoughts first turned to medical education. When Princeton became the site for the institute, Flexner, as the inaugural director, set out to catch the best minds in the world for the ivory tower experiment. The degree-granting side of the experiment quickly fell away. In the exact sciences, where the reputation of the institute was and remains, the selection of staff became relatively easy. Physics and mathematics, by 1930, had been transformed, and there was, Leopold Infeld emphasizes in *Quest*, a consensus about which stars shone brightest. *Pursuit of Genius* details negotiations—many of them successful—with Albert Einstein, Hermann Weyl, Wolfgang Pauli, Niels Bohr, Paul Dirac, Richard Feynman, Emil Artin, Kurt Gödel, and John von Neumann, among others. The book shows how Flexner worked to calm the gaggle of the governing board and smooth the feathers of peacock

professors. Collaborating with Oswald Veblen, he strove to make peace with the Mathematics Department of Princeton University, a competing reservoir of testy and truculent talent (Flexner recruited Veblen from the Mathematics Department, and the two groups of mathematicians shared quarters in Fine Hall on the university campus until 1939). As Nathan Reingold and Ida H. Reingold observed nearly a generation ago in their volume, *Science in America: A Documentary History, 1900–1939*, mathematics in America was a balancing act: Success required drawing on immigrant talent without neglecting native-born and locally-educated minds. Abraham Flexner, an intellectual Jewish confidant of the big bourgeoisie who had married into the literary and Protestant establishment, maintained the balance. (His wife, Anne Crawford Flexner, was a successful dramatist, among whose credits is *Mrs. Wiggs of the Cabbage Patch*.)

Through the first two-thirds of the twentieth century, research in mathematics required little more than a sharp pencil. How much less expensive it is to fund a group of brilliant mathematicians than to support a herd of dairy cattle, run a model high school, or operate a cyclotron. The swamps and cornfields of America could certainly have aspired to something like the mathematical assembly at the Institute for Advanced Study. But no plantation heir, cattle baron, or mining magnate thought to endow an institute for advanced study in the hinterland. Princeton, a bedroom community for the rich and famous, was a natural choice for it. Once Princeton University received the Isaac Wyman bequest in 1910, the same year that Woodrow Wilson left the university's presidency to govern the state of New Jersey, graduate studies rose to world prominence. Classicist Andrew Fleming West, the dean who courted Wyman and benefited from his largess, "was fabled to have run down the road to Trenton to get a copy of the confirming telegram" of the benefactor's death (as reported in Alvin Kernan's memoir, *In Plato's Cave*). And prominent among purveyors of graduate studies at Princeton were the best mathematicians money could buy—they constituted, in Leopold Infeld's view, "a very good department of a rich, distinguished university".

Abraham Flexner, who began as a school teacher, was a generalist. In 1910 he had authored a survey for the Carnegie Foundation for the Advancement of Teaching about American medical education, much of which was bad or bogus; when he joined Rockefeller's General Education Board in 1913, he expanded on the report to bring about an elite stratification in health-care training. (Abraham's brother Simon was, beginning in 1902, director of the Rockefeller Institute in New York.) Abraham Flexner's vision for the Princeton institute ranged across the academic spectrum. As a complement to the exact sciences, he set up a school of economics and also signed on classicists and archaeologists. Here his vision grew clouded and his consultants lacked insight. He hired Erwin Panofsky, but it is fair to say that many of his humanist geese (distinguished in the manner of thousands of humanists) failed to lay a golden egg, even though later appointments were held by Ernst Kantorowicz, Alexandre Koyré, Thomas Kuhn, and Otto Neugebauer. To my eye, Flexner's significant investment in archaeology lacked a persuasive outcome, and his initiative in economics, apparently wedded to sustaining the capitalist avarice that lay at the core of the institute's endowment, until recently led nowhere. Following the demise of the early economics group and the reorganization of the institute under Director J. Robert Oppenheimer beginning in 1947, the social sciences have had a relatively low profile, when not rocked by controversy. One such controversy, in 1972, involved an attempt to bring in sociologist Robert Bellah, an authority on "civil religion" in America, whose nomination brought a howl of protest from mathematician André Weil. The biological and medical sciences never enjoyed a major role at the institute, no doubt in part because of Princeton's absent medical school and relatively undeveloped natural history collections.

Photograph, ca. 1890–1910, Edward Klauber photographer.

Abraham Flexner, circa 1900.

At least in the exact sciences, a sinecure at the institute is a reward for spectacular accomplishment. The hope is that lightning will strike again. Incumbents were certainly not one-trick ponies, but it is not unkind to observe that, in the early decades, all did not repeat the brilliant innovation that brought each of them to Princeton. Leopold Infeld, who worked at the institute with Einstein for two years late in the 1930s, suggests why:

> Is it not the very impact of the external events, the fact that one is in the middle of an active world, that one takes part in the great play of impinging forces which keeps the imagination active, thought vivid and prevents sterility?… Isolation, comfort and security as a reward for work done in the past may destroy the circumstances in which and through which this work was done. Scientific achievement is, as Einstein so often remarked to me, a matter of

> character, and character is formed and developed by the hard struggles of life. Isolation, security, ivory towers, all may prove just as dangerous, or even more so, than too much hardship and bitter fights which destroy the conditions of work. (*Quest*, page 250)

Pursuit of Genius cites Richard Feynman's earthier assessment of the situation in the 1940s:

> I could see what happened to those great minds at the Institute for Advanced Study, who had been specially selected for their tremendous brains and were now given this opportunity to sit in this lovely house by the woods there, with no classes to teach, with no obligations whatsoever. These poor bastards could now sit and think clearly all by themselves, OK? So they don't get an idea for a while: They have every opportunity to do something, and they're not getting any ideas…Nothing happens because there's not enough *real* activity and challenge: You're not in contact with the experimental guys. You don't have to think how to answer questions from the students. Nothing! (page 263).

As Harold Allen Mooz-Kolov reports in his 1976 doctoral dissertation at the University of Michigan, *The Organization of Scientific Elites*, it is a sentiment shared by Abrahm Flexner at the end of his life. Whether or not they were geniuses, whether or not they were people of sterling character, the institute professors cultivated an image of sagacity, and they used their time to reflect on a wide variety of matters. The best of them became something greater. The cloister of acclaimed thinkers acted as a beacon for all intellectuals. Children in rural poverty and in urban tenements came to know that it was okay to think deeply. Oppenheimer's essays, *The Open Mind*, stood on the bookcase in my parents' farmhouse.

From its beginning, the institute has been national news, and people have scrambled for an association with it. It is a quintessential American creation. Over more than seventy years, a postdoctoral appointment there has sped thousands of careers. The institute has been selective in the knowledge that it cultivates, but more than any other community in recent times, it incarnates the museum at Alexandria—or perhaps offers an intimation of Isaac Asimov's Second Foundation on Trantor. Abraham Flexner can be forgiven if (as *Pursuit of Genius* contends) he stayed too long at the helm of his ship.

By focusing on the wrangling that lies at the heart of running any institution of higher learning, *Pursuit of Genius* underestimates the extent to which the times made the institute. Indeed, one can imagine a successful outcome with any one of a dozen educators at the helm. Reading between the lines, a reader senses that Flexner's limitations, rather than his prescience, account for the institute's unique features. He attached fundamental importance to the salary and the prestige of chairs, rather than to infrastructure; never having administered a university, he was unenthusiastic about developing a mechanism for granting degrees; his lengthy negotiations with complex personalities—pursuing genius—indirectly led to a focus on postdoctoral and visiting positions—cultivating genius.

Although, during his tenure as director, Oppenheimer was attracted to the philosophy of American pragmatism (as reported by Silvan S. Schweber in his collection, *Einstein & Oppenheimer*), the Institute for Advanced Study represents the preeminence of supremely useless knowledge in an environment that is generally seen as the archetype of practicality—America does pride itself on practicality, on following the maxims of Benjamin Franklin and the prejudices of Henry Ford. Notwithstanding Flexner's desire to have economist tinkers rub shoulders with scholarly thinkers, his staff and fellows focused on abstraction. He envisioned no chairs for engineers, public-health officers, or psychotherapists. The Institute for Advanced Study began as an ark at a time of war, oppression, and discouragement.

In early twentieth-century America, uselessness demarcated class. The nineteenth-century mantra for enforcing class distinctions—religiosity—dominated both private and secular institutions of higher learning. Indeed, the Ethical Culture movement (the cradle of Oppenheimer's philosophical understanding) was religion without dogma for the elite of America. By the early 1930s, places of religious devotion had ceded to great palaces for abstract learning—the New York Public Library, the American Museum of Natural History, the Metropolitan Museum of Art, the Cloisters, the Boston Museum of Fine Arts, the Philadelphia Museum of Art, Widener Library, the Field Museum—which focused volatile minds on lofty things and dignified the standing of the donors. The world's largest research establishment, the Carnegie Institution of Washington, focused largely on impractical truths. Purity was also the focus of the Association of American Universities and the National Research Council, which met in halls from which the great majority of scholars and scientists were excluded.

A call for purity at high-minded private institutions fit with the anxieties of wealthy Americans eyeing waves of immigrants and their aggressive, practical enterprise. Nothing could be more pure, more at the center of liberal education, than languages and mathematics, according to Henry

Courtesy of the Archives of the Institute for Advanced Study.

Fuld Hall, circa early 1960s.

Merritt Wriston, president of Brown University during its rise in mathematics under the graduate dean Roland George Dwight Richardson (who was secretary of the AMS from 1921 to 1940). Respect for purity and abstraction also animated Princeton's graduate dean Andrew Fleming West, who had an uncanny ability to fish shekels out of the pockets of plutocrats; it guided Henry Burchard Fine, simultaneously dean of the Princeton faculty, dean of the science departments, and chair of mathematics. (Like Brown's Richardson, Princeton's Fine—president of the AMS in 1911–12—was a proponent of "applied mathematics", by which was meant not mathematics used by engineers but rather the mathematical elaboration of natural sciences, especially physics, in the sense of the Mathematical Institute at the University of Göttingen.)

This is not to say that nothing of immediate, practical significance came from Flexner's collegium. Flexner's successor Frank Aydelotte promoted an initiative in weather prediction, and John von Neumann, while at the institute, played a fundamental role in developing electronic computers, notably the principles of core memory. (A universal intellect, he, like Einstein, examined the parts of the world he found interesting, and he, like Einstein, put up with jealous detractors.) Maybe, too, the economists appointed by Flexner were implicated in human suffering, whether alleviating it or promoting it. The point is that the institute was conceived as a place where the spirit of genius could blow where it listeth. A call from Flexner and his successors has prevented distinguished thinkers from fawning before insensitive patrons, in the manner of Leonardo da Vinci and Niccolò Machiavelli when they boarded with Cesare Borgia.

It is widely held that the institute has declined over the past generation or so. Possibly so in the exact sciences, probably so in the human sciences. There is some comfort in observing that, even if they are not of society, institutions are in society. History exhibits fashions of the intellect. Postmodernity has heaped scorn on Robert K. Merton's four institutional imperatives of science (universalism, communism, disinterestedness, organized skepticism). Today, immature minds are instructed that success is measured only in solipsism, in personal gratification; the message retained by many talented young people is to accumulate wealth rather than to seek truth. But as Henry Rosovsky notes in his memoir, *The University: An Owner's Manual*, an institution outlives its staff. Notwithstanding perilous times ahead, profundity shall once more become fashionable, and the institute will likely play a role in that renascence. And if this were not enough, all in all, considering the alternatives, the Institute for Advanced Study is still *primus inter pares*.

Even taking into account the respect accorded pure science early in the twentieth century, the Institute for Advanced Study came into being only because, as *Pursuit of Genius* points out, Bamberger sold his store shortly before the stock market crash that signaled the start of the Great Depression. The times are different now, as we perch on the rim of a Second Great Depression. Today, as Paul Forman has persuasively argued in his publications, science is an epicycle on the great wheel of technology—on artifice—rather than being the luminous body around which technology whirls. In such neologisms as *technoscience* and *STEM fields*, technology has the place of pride. Technology commands the attention of the bureaucracy at the Arlington headquarters of the National Science Foundation. There is a massive campaign to force universities toward practical—that is to say, lucrative—enterprises. Woe to the university today without offices dedicated to intellectual property, technology transfer, and "auxiliary enterprises".

Leading speakers for higher learning have ceased to defend the very thing they represent. They have forgotten that their institutions do not manufacture artifice so much as understand it. (Not for nothing, and notwithstanding postmodernist relativizers, is "artificial" considered the opposite of "natural".) Understanding artifacts (and using them) belongs in the province of scientists; understanding how people interact with artifacts is the burden of humanists. The finest artisans and builders, the most imaginative musicians and writers, carry out their enterprise in the agora, not in the academy. Technology, that is to say artifice, will do well whether or not institutions of higher learning focus on it. Technology powered Rome, whose accomplishments in science and institutions devoted to science are imperceptible. People in Medieval Europe did not neglect innovative technology, even though there were no academic institutions promoting it. So, too, in large measure, is the story of the Industrial Revolution. In the present darkness and uncertainty, as universities turn into trade schools, we need, above all, to build on the model of the Institute for Advanced Study.

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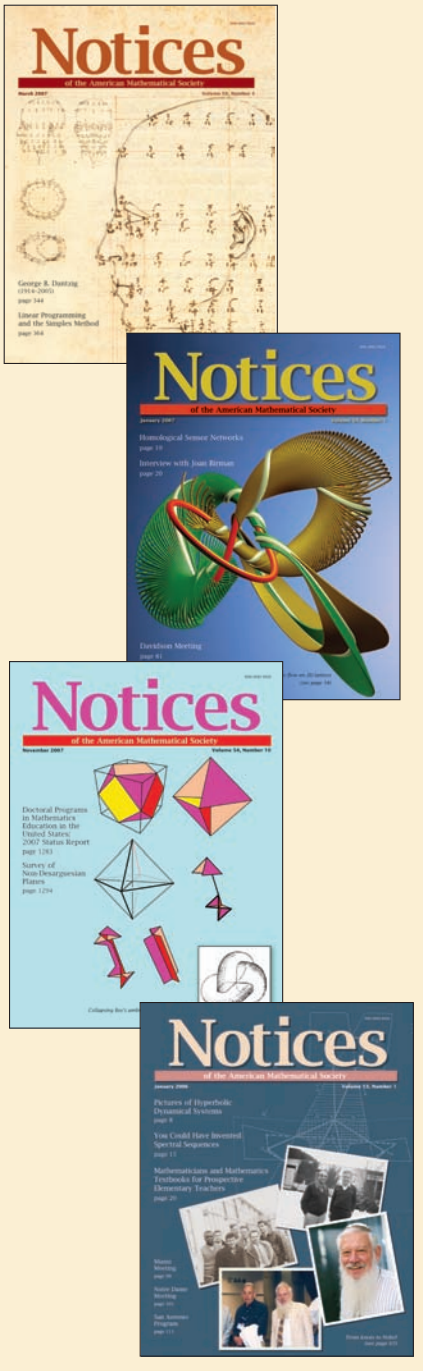

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Computable Fields and Galois Theory

Russell Miller

An irreducible polynomial has a solution in radicals over a field $\mathcal{F}$ if and only if the Galois group of the splitting field of the polynomial is solvable. This result is widely considered to be the crowning achievement of Galois theory, and is often the first response when a mathematician wants to describe the beauty of mathematics. Yet with the development of a rigorous theory of algorithms, we can ask further questions about the process of finding roots of a polynomial. Are there methods other than solution in radicals that might suffice? For that matter, when one does not even know which radicals are contained in a given field, how useful is it to have a solution in radicals?

In this article we begin to address such questions, using computability theory, in which we determine, under a rigorous definition of algorithm, which mathematical functions can be computed and which cannot. The main concepts in this area date back to Alan Turing [15], who during the 1930s gave the definition of what is now called a *Turing machine*, along with its generalization, the *oracle Turing machine*. In the ensuing seventy years, mathematicians have developed a substantial body of knowledge about computability and the complexity of subsets of the natural numbers. It should be noted that for most of its history, this subject has been known as *recursion theory*; the terms *computable* and *recursive* are to be treated as interchangeable.

Computable model theory applies the notions of computability theory to arbitrary mathematical structures. Pure computability normally considers functions from $\mathbb{N}$ to $\mathbb{N}$, or equivalently, subsets of finite Cartesian products $\mathbb{N} \times \cdots \times \mathbb{N}$. Model theory is the branch of logic in which we consider a structure (i.e., a set of elements, called a domain, with appropriate functions and relations on that domain) and examine how exactly the structure can be described in our language, using symbols for those functions and relations, along with the usual logical symbols such as negation, conjunction, $(\exists x)$, and $(\forall x)$. To fit this into the context of computability, we usually assume that the domain is $\mathbb{N}$, the natural numbers (including 0), so that the functions and relations become the sort of objects studied by computability theorists. In this article, we mostly consider the specific case of a computable field, which will be defined below, after a brief introduction to computability.

Basic Computability Theory

We provide here definitions, emphasizing intuition, and some basic theorems. Rigorous versions can be found in any standard text on computability, including [6], [12], and [13].

For our purposes, a *Turing machine* is an ordinary computer, operating according to a finite program, which accepts a natural number as input and runs its program in discrete steps on that input. The machine has arbitrarily much memory available to it (on a tape, in the usual conception), but in one step it can write only a single bit (0 or 1) in a single location, and so after finitely many steps, it will have used only finitely much of its

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memory. One specific instruction in the program tells the machine to halt; if this instruction is ever reached, then the program beeps to tell us that it is finished, and its output is the total number of 1's written on its memory tape. Since only finitely many steps can have taken place so far, this output must also be a natural number. Computer scientists worry exceedingly about how many steps are required for the machine to halt and how much of the memory tape is used before it halts, but for a computability theorist, the principal question is whether the machine ever halts or not, and if so, what its output is. Of course, the instructions can go into an infinite loop, or avoid the halting instruction in other ways, so it is quite possible that a program on a given input never halts at all.

A function $f : \mathbb{N} \to \mathbb{N}$ is said to be *computable* if there is a Turing machine that computes f. Specifically, on each input $n \in \mathbb{N}$, the program should eventually halt with output $f(n)$. More generally, we consider *partial functions* $\varphi : \mathbb{N} \to \mathbb{N}$, for which (despite the similarity of notation) the domain is allowed to be any subset of $\mathbb{N}$. The possibility that a program never halts makes the partial functions a more natural class for our definitions, since every Turing machine computes some partial function, namely that φ whose domain is the set of inputs on which the machine halts, with $\varphi(n)$ being the output of the machine for each such input n. We write $\varphi(n)\downarrow$, and say that $\varphi(n)$ *converges*, if $n \in \mathrm{dom}(\varphi)$; otherwise $\varphi(n)$ *diverges*, written $\varphi(n)\uparrow$.

The importance of the restriction that a Turing machine must use a *finite* program is now clear, for an infinite program could simply specify the correct output for each possible input. On the other hand, with this restriction, we have only countably many programs in all: there are only finitely many possible instructions, so for each $n \in \mathbb{N}$, only finitely many programs can contain exactly n instructions. Hence only countably many partial functions are computable, with the remaining (uncountably many) ones being noncomputable. It is not hard to define a noncomputable function: just imitate Cantor's diagonal proof that $\mathbb{R}$ is uncountable.

A subset $S \subseteq \mathbb{N}$ is said to be *computable* if and only if its characteristic function χ_S is computable. (Of course, the characteristic function is *total*, i.e., its domain is all of $\mathbb{N}$.) Easy examples include the finite sets, the eventually periodic sets, the set of prime numbers, and any set that can be defined in the language of arithmetic without using unbounded quantifiers $\forall$ and $\exists$. (For more of a challenge, find a set that is computable but cannot be defined using only bounded quantifiers.) Another useful concept is *computable enumerability*: S is computably enumerable, abbreviated *c.e.*, if it is empty or is the range of some total computable function f. Intuitively, this says that there is a mechanical way to list out the elements of S: just compute $f(0)$, then $f(1)$, etc., and write each one on our list. Computably enumerable sets are "semi-computable", in the following sense, which the reader should try to prove.

Fact 1. *A subset $S \subseteq \mathbb{N}$ is computable if and only if both S and its complement $\overline{S}$ are computably enumerable.*

Fact 2. *A set S is computably enumerable if and only if S is the range of a partial computable function, if and only if there is a computable set R such that $S = \{x : \exists y_1 \cdots \exists y_k\ (x, y_1, \ldots y_k) \in R\}$, if and only if S is the domain of a partial computable function.*

For the R in this fact, we need to consider subsets of Cartesian products $\mathbb{N}^k$ as well. For this we use the function

$$\beta_2(x, y) = \frac{1}{2}(x^2 + y^2 + x + 2xy + 3y),$$

which is a bijection from $\mathbb{N}^2$ onto $\mathbb{N}$. (In checking this, bear in mind that for us 0 is a natural number.) β_2 feels computable; it would be computable if we allowed the input (x, y) to be simulated on the input tape by x 1's, followed by a 0 and then y 1's. Alternatively, notice that if π_1 and π_2 are projections, then both functions $\pi_i \circ \beta_2^{-1}$ are computable, and so given x and y, we could search through all possible outputs $n \in \mathbb{N}$ until we found one for which $\pi_1(\beta_2^{-1}(n)) = x$ and $\pi_2(\beta_2^{-1}(n)) = y$. So we may use this bijection β_2 to treat $\mathbb{N}^2$ as though it were just $\mathbb{N}$, and then define $\beta_3(x, y, z) = \beta_2(x, \beta_2(y, z))$ and so on. Indeed, the bijection β defined by

$$\beta(x_1, \ldots, x_k) = \beta_2(k, \beta_k(x_1, \ldots, x_k))$$

maps the set $\mathbb{N}^*$ of all finite sequences of natural numbers bijectively onto $\mathbb{N}$. This gives us a way of allowing polynomials from $\mathbb{N}[X]$ to be the inputs to a computable function.

Now that we know how to handle tuples from $\mathbb{N}$ as inputs, we can see that there is a *universal Turing machine*. The set of all possible programs is not only countable, but can be coded bijectively into the natural numbers in such a way that a Turing machine can accept an input $e \in \mathbb{N}$, decode e to figure out the program it coded, and run that program. The universal Turing machine accepts a pair (e, x) as input, decodes e into a program, and runs that program on the input x. It defines a partial computable function $\varphi : \mathbb{N}^2 \to \mathbb{N}$, which can imitate every partial computable function ψ: just fix the correct e, and we have $\psi(x) = \varphi(e, x)$ for every $x \in \mathbb{N}$ (and with $\psi(x)\uparrow$ if and only if $\varphi(e, x)\uparrow$, moreover). This enables us to give a computable list of all partial computable functions, which we usually write as $\varphi_0, \varphi_1, \ldots$, with $\varphi_e(x) = \varphi(e, x)$ for a fixed universal partial computable function φ. In contrast, there is no computable list of all the total computable functions (i.e., those with

domain $\mathbb{N}$); if there were, one could use it to diagonalize and get a new total computable function not on the list!

Likewise, using Fact 2, this yields a computable list of all computably enumerable sets $W_0, W_1, \ldots$, with $W_e = \mathrm{dom}(\varphi_e)$. We can view them as the rows of the universal c.e. set $W = \mathrm{dom}(\varphi) = \{(e,x) : \varphi_e(x)\downarrow\} \subseteq \mathbb{N}^2$. On the other hand, there is no such computable listing of all computable sets.

The principal remaining fact we will need is simply stated.

Fact 3. *There exists a c.e. set that is not computable.*

A simple definition of one such is

$$K = \{e : \varphi_e(e)\downarrow = 0\}.$$

The idea is that φ_e cannot equal χ_K, because $e \in K$ if and only if $\varphi_e(e) = 0$ if and only if φ_e guesses that e is *not* in K. Of course, if $\varphi_e(e)$ never converges, we never add e to K, and again we see that $\chi_K \neq \varphi_e$, simply because $e \in \mathrm{dom}(\chi_K)$. Many similar sets can be defined; the famous one, the domain of the function φ computed by the universal Turing machine, is usually called the *Halting Problem*, since it tells you exactly which programs converge on exactly which inputs. If it were computable, then we could use it to compute K, which is impossible. Indeed, if $\mathrm{dom}(\varphi)$ were computable, then every c.e. set would be computable.

Computable Fields

When considering fields, we normally work in a language that includes the addition and multiplication symbols, regarded as binary functions, and two constant symbols to name the identity elements, along with all standard logical symbols. A field $\mathcal{F}$ then consists of a set F of elements (called the *domain* of the field, but not to be confused with the separate notion of a ring without zero-divisors), with two elements of F distinguished as the two constants, and with two binary functions on F, represented by the symbols $+$ and $\cdot$, all satisfying the standard field axioms.

For a field to be computable, we want to be able to compute the two field operations in this language. Our notion of computability is defined over $\mathbb{N}$, so we index the elements of the field using $\mathbb{N}$. Of course, this immediately eliminates all uncountable fields from the discussion! At the end of this article we mention a possible approach to this problem.

Definition 4. A *computable field* is a field $\mathcal{F}$ with domain $\{a_0, a_1, \ldots\}$ and with two computable total functions f and g such that for all $i, j \in \mathbb{N}$,

$$a_i + a_j = a_{f(i,j)} \text{ and } a_i \cdot a_j = a_{g(i,j)}.$$

This simply says that we can compute the basic field operations in $\mathcal{F}$ using Turing machines. In fact, in most of computable model theory one takes $\mathbb{N}$ itself to be the domain. However, we will wish to use the symbols 0 and 1 to refer to the identity elements of the field (and perhaps 2 to refer to the sum $1+1$, etc.), so we use the notation a_i to avoid confusion.

Since we have constant symbols $0 = a_r$ and $1 = a_s$ for some r and s, we ought officially to say that these numbers r and s are computable as well. However, any single number is in some sense always computable; we can add this information to any finite program and still have a finite program. If the language had happened to have infinitely many constant symbols, presumably indexed somehow by $\mathbb{N}$, then we would have required that their values in the domain be computable from those indices. Moreover, we have a stronger answer to this question: knowing how to compute f and g allows us to identify the identity elements. Just compute $f(0,0), f(1,1), \ldots$ until you find the (unique) r with $f(r,r) = r$, and then a_r must be the zero in $\mathcal{F}$. Similarly, 1 is the unique element $a_s \neq a_r$ for which $g(s,s) = s$.

A related question is whether it matters that we did not include other field operations, such as subtraction or reciprocation, in our language. If we had included them, then we would require those operations to be computable as well, of course. However, our definition was equivalent.

Lemma 5. *In a computable field, the unary operations of negation and reciprocation and the binary operations of subtraction and division are all computable.*

Proof. To find the negative of any a_n, just compute $f(0,n), f(1,n), \ldots$ until you find an m with $f(m,n)$ equal to that r with $a_r = 0$. Then a_m is the negative of a_n, and defining subtraction is now easy as well. Reciprocation is similar, using g, and division follows, except that now the program must check that the input n is not r itself. (Otherwise the search would continue forever!) If the input is r, the program for reciprocation should just output r itself, or some other artificial device to indicate that it has detected division by zero and does not intend to follow through on its search. □

As a first example, there is a computable field $\mathcal{F}$ isomorphic to the field $\mathbb{Q}$ of rational numbers. For this we wish to think of each a_i as a fraction with integer numerator and natural-number denominator, without letting our domain repeat any fractions. Since we have the computable bijection β_2 from page 799, we can define $h(0) = 2 = \beta_2(0,1)$ and $h(n+1)$ to be the least $k > h(n)$ for which $\pi_1(\beta_2^{-1}(k))$ is relatively prime to $\pi_2(\beta_2^{-1}(k))$. This allows us to define computable functions $\mathsf{num}(2n) = \pi_1(\beta_2^{-1}(h(n)))$ and $\mathsf{denom}(2n) = \pi_2(\beta_2^{-1}(h(n)))$ for all $n \in \mathbb{N}$, giving

the numerators and denominators of the field elements $a_0, a_2, a_4, \ldots$. We treat a_{2n+1} as the negative of a_{2n+2}, and define addition and multiplication on the domain $\{a_0, a_1, a_2, \ldots\}$ by doing arithmetic on fractions (which *does* follow a simple algorithm, all experience teaching students to the contrary!).

The reader is invited to attempt to build computable fields of isomorphism types such as $\mathbb{Q}(X)$, $\mathbb{Q}(\sqrt{2})$, $\mathbb{Q}(X_1, X_2, \ldots)$, and other well-known countable fields. $\mathbb{Z}_p(X_1, X_2, \ldots)$ is also possible, of course. Definition 4 ought to be tweaked to allow finite fields, of course, since such fields in some sense must be computable, with the algorithms for the field operations being given by finite tables of values. We avoided this in order to keep the definition simple, but it would be better to allow domains of the form $\{a_0, \ldots, a_m\}$ as well.

Notice, however, that it is quite possible for a computable field to be isomorphic to a field that is not computable. Strictly speaking, $\mathbb{Q}$ itself is not computable, since its domain is not in the proper form. More than this, however, there are isomorphic copies of $\mathbb{Q}$ with domain $\{a_0, a_1, \ldots\}$ in which the operations are not computable. Indeed, any of the uncountably many permutations of $\mathbb{N}$ (i.e., bijections from $\mathbb{N}$ onto itself) produces a distinct copy of the same field, with the same domain but the operations lifted via the permutation, and almost all of these are noncomputable. So we should not say that the isomorphism type of a field is computable; rather we say that a field (or its isomorphism type) is *computably presentable* if it is isomorphic to a computable field.

Indeed, we already have the tools to build a countable field that is not computably presentable. Consider the noncomputable c.e. set K from Fact 3. Write p_n for the n-th prime number ($p_0 = 2$, $p_4 = 11$, etc.), and let $\mathcal{E}_{\overline{K}}$ be the following extension of $\mathbb{Q}$:

$$\mathcal{E}_{\overline{K}} = \mathbb{Q}[\sqrt{p_n} \ : \ n \notin K].$$

Now the set of primes is computable, and so in any field of characteristic 0, it is easy to list out the prime numbers $p_0, p_1, \ldots$, just by adding 1 to itself. (Specifically, the function h with $p_n = a_{h(n)}$ is computable.) If $\mathcal{F}$ were a computable field isomorphic to $\mathcal{E}_{\overline{K}}$, then the following process would contradict the noncomputability of K. Each time a field element appears in $\mathcal{F}$ whose square equals p_n for any n, enumerate that n into a set W. By the definition of $\mathcal{E}_{\overline{K}}$, this W would equal the complement $\overline{K}$, and we would have a computable enumeration of this complement, which is impossible, by Fact 1.

In light of this, it may seem surprising that the field $\mathcal{E}_K = \mathbb{Q}[\sqrt{p_n} \ : \ n \in K]$ is computably presentable. Yet it is: we will build a computable presentation of $\mathcal{E}_K$. To "build" a field usually means that we give finitely much of it at a time, first defining the addition and multiplication functions only on the domain $\{a_0, \ldots, a_j\}$, then extending them to $\{a_0, \ldots, a_{j+1}\}$, and so on. We do this according to an algorithm, and if we wish later to compute the field addition or multiplication, we simply run this same algorithm until it defines the sum or product we seek. (Of course, our algorithm must decide within finitely much time which a_k is to be the sum $a_i + a_j$; and once it has decided, it may not change its mind!)

So we start building a computable presentation of $\mathbb{Q}$, similar to the one given above, and simultaneously start enumerating K. (Think of a timesharing procedure, allowing us to do both these processes at once.) Whenever a new element n appears in K, we continue building our field until the element p_n has appeared in it, then stop for long enough to define the multiplication so that the next new element is the square root of p_n. Then we continue building the field, always treating this new element as the square root of p_n when defining the addition and multiplication. Since every $n \in K$ eventually appears in our enumeration, this builds a computable field isomorphic to $\mathcal{E}_K$.

The key here is that the statement "p_n has a square root" is an existential formula, with free variable n:

$$(\exists x)[x \cdot x = (1 + 1 + \cdots + 1) \ (p_n \text{ times})].$$

The statement within the square brackets defines a computable set, since one can rewrite the $(1 + 1 + \cdots + 1)$ as $a_{h(n)}$, with h as defined just above. Therefore, in a computable field, the set of numbers n satisfying this existential formula is a computably enumerable set, by Fact 2. K itself is c.e., so having this set equal K (as in $\mathcal{E}_K$) is not a problem. Indeed, we could build a similar field $\mathcal{E}_W$ for any c.e. set W. However, since the complement $\overline{K}$ is not c.e., the field $\mathcal{E}_{\overline{K}}$ is not computably presentable.

$\mathcal{E}_K$ is not without its complications, however. A standard question for a field $\mathcal{F}$ is the existence of a *splitting algorithm* for $\mathcal{F}$. That is, given a polynomial $p(X) \in \mathcal{F}[X]$, we want an algorithm that produces the irreducible factors of $p(X)$ in $\mathcal{F}[X]$. Of course, if one knows that $p(X)$ is not itself irreducible, then one can search through $\mathcal{F}[X]$ for a nontrivial factorization (using our function β from page 799 to list out all elements of $\mathcal{F}[X]$), and then repeat the process recursively for each factor. So the splitting algorithm comes down to being able to decide whether a given polynomial is irreducible or not. Formally, a computable field $\mathcal{F}$ has a splitting algorithm if and only if the set of irreducible polynomials in $\mathcal{F}[X]$ is a computable set. (Again, we use β as a canonical translation between $\mathbb{N}^*$, i.e., the set of polynomials, and $\mathbb{N}$.)

Kronecker gave a splitting algorithm for $\mathbb{Q}$ itself. In fact, he showed that every finite extension of $\mathbb{Q}$ has a splitting algorithm, using the following.

Theorem 6 (Kronecker [5]; see also [1] or [16]). *If a field $\mathcal{L}$ has a splitting algorithm, then so does $\mathcal{L}(X)$ for any X transcendental over $\mathcal{L}$. When x is algebraic over $\mathcal{L}$, again $\mathcal{L}(x)$ has a splitting algorithm, but it requires knowledge of the minimal polynomial of x over $\mathcal{L}$.*

The algorithms for algebraic and transcendental elements are different, so for an arbitrary extension $\mathcal{L}(t)$, one needs to know whether t is algebraic or not, and if it is, one also needs to know the minimal polynomial of t over $\mathcal{L}$. It is possible to exploit this need directly to produce computable fields without splitting algorithms, but in fact we have an example already. If the computable field $\mathcal{E}_K$ had a splitting algorithm, then for any input n, we could find the element p_n in $\mathcal{E}_K$ and ask whether the polynomial $(X^2 - p_n)$ splits in $\mathcal{E}_K[X]$ or not. The answer would tell us whether $n \in K$, by definition of $\mathcal{E}_K$, and so K would be computable, contrary to Fact 3. So we have shown:

Lemma 7. *There exists a computable field without a splitting algorithm.* □

Algorithms and Galois Theory

The famous results of classical Galois theory are concerned not with general algorithms for finding roots of polynomials, but rather with specific formulas for those roots, or the absence of any such formulas. The most famous result, the Ruffini-Abel Theorem, states that there is no formula using radicals for a root of a general fifth-degree polynomial. It does not consider other possible algorithms for computing such a root. On the other hand, radicals are often taken for granted in these formulas, with the underlying assumption (from an algorithmic point of view) that radicals are somehow known: that for any element x of the field, one can effectively find an n-th root of x, for any n. Of course, a field need not even contain n-th roots of all its elements, and in the computable field $\mathcal{E}_K$ already constructed above, the set of elements possessing square roots in the field is not a computable set. So, in considering Galois-style questions for computable fields, we may wind up with different answers from the classical Galois-theoretic results.

Of course, in computability theory, our algorithms often involve simple (perhaps even simple-minded) search procedures. An analogous situation arose in Hilbert's Tenth Problem, which demands an algorithm for determining whether an arbitrary Diophantine equation (i.e., a polynomial in $\mathbb{Z}[X_1, \ldots, X_n]$, for any n) possesses a solution in $\mathbb{Z}^n$. Intuitively, the real question is to find such a solution, not merely to prove that one exists. However, a simple search procedure suffices: just check, for each $m \geq 0$ in order, whether any $\vec{a} \in \mathbb{Z}^n$ with $\sum_i |a_i| = m$ solves the equation. This algorithm certainly produces a solution, assuming only that one exists; the difficulty is that if no solution exists, the algorithm will simply run forever, without ever giving an answer. So the question of effectively finding a solution reduces to Hilbert's question of how to decide whether such a solution exists. Matijasevič proved in [7], building on work of Davis, Putnam, and Robinson, that no algorithm exists that will compute the set of Diophantine equations possessing solutions, by showing that such an algorithm would allow us to compute K (and all other c.e. sets).

Dealing with polynomials $p(X)$ with coefficients in a computable field $\mathcal{F}$ creates a similar situation. We can search for a root of p in $\mathcal{F}$, just by computing $p(a_0), p(a_1), \ldots$ until we find a root. Again, the real question is determining whether this search will ever halt, i.e., whether $\mathcal{F}$ contains a root of $p(X)$. By definition, $\mathcal{F}$ has a *root algorithm* if the set $\{p(X) \in \mathcal{F}[X] : (\exists a \in \mathcal{F})\ p(a) = 0\}$ is computable.

A splitting algorithm for $\mathcal{F}$ would solve this problem, of course, by giving us a factorization of $p(X)$ into components irreducible in $\mathcal{F}[X]$: p would have as many roots as it has linear components. So a splitting algorithm yields a root algorithm. We will consider the converse after stating Rabin's Theorem below.

Thinking of Galois theory, we could also define a *radical algorithm*, for deciding whether polynomials of the form $(X^n - a)$ have roots in $\mathcal{F}$, for arbitrary n and a. In fact, we will also break down this question by degree, defining the following sets:

$$P_n(\mathcal{F}) = \{p(X) \in \mathcal{F}[X] : \deg(p) = n \ \& \ (\exists a \in \mathcal{F})\ p(a) = 0\}$$

$$R_n(\mathcal{F}) = \{x \in \mathcal{F} : (\exists y \in \mathcal{F})\ y^n = x\}.$$

For $n > 1$, none of these sets need be computable. The field $\mathcal{E}_K$ showed this for R_2, hence also for P_2, and similar constructions hold for larger n. On the other hand, the quadratic formula proves that if $R_2(\mathcal{F})$ is computable, then so is $P_2(\mathcal{F})$, since one need only decide whether the discriminant of a quadratic polynomial lies in $R_2(\mathcal{F})$. Since the converse is immediate, P_2 and R_2 may be said to be *equicomputable*.

(A more precise term than equicomputable is *Turing-equivalent*, and indeed in this case *computably isomorphic*. These indicate that, under various definitions, $P_2(\mathcal{F})$ and $R_2(\mathcal{F})$ are "equally hard" to compute. Turing-equivalence, for example, means that if one had an oracle that would answer questions of the form "Is $p(X)$ in $R_2(\mathcal{F})$?" for arbitrary $p(X)$, one could write a program that would ask such questions of the oracle and use the answers to decide membership of arbitrary polynomials in $P_2(\mathcal{F})$; and vice versa with an oracle for $P_2(\mathcal{F})$. Thus, even in the case when these are

both noncomputable, they are at the same level in the hierarchy of noncomputability known as the Turing degrees. In this article, for the sake of simplicity, we have studiously avoided the notions of Turing degree and oracle computability; they may be found in any standard text on the subject.)

$P_3(\mathcal{F})$ and $R_3(\mathcal{F})$ are not in general equicomputable, however. The cubic formula uses not only cube roots, but also square roots, and so $P_3(\mathcal{F})$ is computable if both $R_2(\mathcal{F})$ and $R_3(\mathcal{F})$ are. The converse fails: indeed, our field $\mathcal{E}_K$ serves yet again as the counterexample. Given $p(X)$ of degree 3, we can enumerate elements $n_1, n_2, \ldots$ of K until we find a subfield $(\mathcal{E}_K)_j = \mathbb{Q}[\sqrt{p_{n_1}}, \ldots, \sqrt{p_{n_j}}]$ that contains all coefficients of $p(X)$. Now we know a splitting algorithm for $(\mathcal{E}_K)_j$, no matter how large j may be, and so we may check whether $p(X)$ is reducible in $(\mathcal{E}_K)_j[X]$. If so, then $p(X)$ has a root in $(\mathcal{E}_K)_j$, since one factor must be linear. If not, then it cannot have any root anywhere in $\mathcal{E}_K$, since any new root r appearing in some further finite extension of $\mathbb{Q}$ would have minimal polynomial $p(X)$ over $(\mathcal{E}_K)_j$, which is impossible, because $p(X)$ has degree 3 and all subsequent extensions of $(\mathcal{E}_K)_j$ are extensions of degree 2^k for some k. Thus $P_3(\mathcal{E}_K)$ is computable, and hence so is $R_3(\mathcal{E}_K)$, yet $R_2(\mathcal{E}_K)$ is not.

The formula for roots of fourth degree polynomials can be expressed using only square roots and cube roots, of course, and so $P_4(\mathcal{F})$ is computable whenever $R_2(\mathcal{F})$ and $R_3(\mathcal{F})$ both are. We encourage the reader to consider possible converses, perhaps involving computability of $P_3(\mathcal{F})$ as well (and $P_2(\mathcal{F})$, except that this is equicomputable with $R_2(\mathcal{F})$, of course). The complete omission of $R_4(\mathcal{F})$ from this discussion is justified by the following general lemma and its corollary.

Lemma 8. *Fix any computable field $\mathcal{F}$ and any $n, k > 0$ in $\mathbb{N}$. Then $R_{nk}(\mathcal{F})$ is computable if and only if both $R_n(\mathcal{F})$ and $R_k(\mathcal{F})$ are.*

Proof. For the forward direction, let m be the number of (nk)-th roots of unity in a computable field $\mathcal{F}$ with $R_{nk}(\mathcal{F})$ computable, and let x be an arbitrary element of $\mathcal{F}$. We check whether $x^k \in R_{nk}(\mathcal{F})$. If not, then certainly $x \notin R_n(\mathcal{F})$. If so, then either $x = 0$ (so $x \in R_n(\mathcal{F})$), or $\mathcal{F}$ must contain exactly m elements $y_1, \ldots, y_m$ with $y_i^{nk} = x^k$, because the quotients $\frac{y_i}{y_1}$ are precisely the (nk)-th roots of unity. We check whether $y_i^n = x$ for any $i \le m$. If so, then of course $x \in R_n(\mathcal{F})$. If not, then $x \notin R_n(\mathcal{F})$, because any y with $y^n = x$ would have $y^{nk} = x^k$, forcing $y = y_i$ for some $i \le m$. Thus $R_n(\mathcal{F})$ is computable, and likewise for $R_k(\mathcal{F})$.

The converse is similar, once we know the number of n-th roots of unity in $\mathcal{F}$: check whether a nonzero x has any n-th roots in $\mathcal{F}$, and if so, find them all and check whether any of them has a k-th root. □

Corollary 9. *For any computable field $\mathcal{F}$ and any $n > 0$, $R_n(\mathcal{F})$ is computable if and only if, for all primes p dividing n, $R_p(\mathcal{F})$ is computable.* □

As a technical aside, the proof of Lemma 8 was *nonuniform*; it required specific knowledge about $\mathcal{F}$ and about (nk). The forward direction, for instance, claims only that for every $\mathcal{F}$ with $R_{nk}(\mathcal{F})$ computable, there exists an algorithm for computing $R_n(\mathcal{F})$, and this is true. In order to know which algorithm it is, however, one needs to know the number of (nk)-th roots of unity in $\mathcal{F}$, and in general this number is not computable: for $nk > 2$, there is no algorithm that takes as input the programs for addition and multiplication in a computable field and outputs the number of (nk)-th roots of unity in that field. So the proof was not uniform in $\mathcal{F}$. Nor was it uniform in (nk): the reader may already be able to construct a single computable field $\mathcal{E}$ for which every individual $R_p(\mathcal{E})$ is computable, but the set $\{\langle x, n\rangle : x \in R_n(\mathcal{E})\}$ is not.

Rabin's Theorem

To go further, we will want to consider algebraically closed fields (or ACF's). The definitive result on computable algebraic closures of computable fields was given by Michael Rabin. For a full proof, see [11]; some discussion also appears in [9]. We give his name to the type of embedding we wish to consider.

Definition 10. Let $\mathcal{F}$ and $\mathcal{E}$ be computable fields. A function $g : \mathcal{F} \to \mathcal{E}$ is a *Rabin embedding* if:

- g is a homomorphism of fields; and
- $\mathcal{E}$ is both algebraically closed and algebraic over the image of g; and
- g is a computable function. (More precisely, there is a total computable h with $g(a_n) = b_{h(n)}$ for all n, where $\mathcal{F}$ has domain $\{a_0, a_1, \ldots\}$ and $\mathcal{E}$ has domain $\{b_0, b_1, \ldots\}$.)

Thus $\mathcal{E}$ is the algebraic closure of $\mathcal{F}$ in a strong way: we actually have $\mathcal{F}$ as a subfield of $\mathcal{E}$, using the computable isomorphism g, and that subfield is computably enumerable, since (the indices of) its elements form the range of a total computable function. It is not hard to show that all countable algebraically closed fields are computably presentable, but when $\mathcal{F}$ has infinite transcendence degree (and we cannot compute a transcendence basis for $\mathcal{F}$; see [8] or [9]), it is not obvious that a Rabin embedding of $\mathcal{F}$ exists. Moreover, we would like the image of our embedding to be a computable subfield of $\mathcal{F}$, not just a c.e. subfield. Rabin resolved these difficulties with his celebrated theorem. Part 1 is the heart of the theorem, but Part 2 is the more pleasing result and is more often cited. The proof of Part 2 is readily understandable and readable at this level; a sketch appears in [9].

Theorem 11 (Rabin [11])**.** *Let $\mathcal{F}$ be any computable field.*

(1) *There exists a computable ACF $\overline{\mathcal{F}}$ with a Rabin embedding of $\mathcal{F}$ into $\overline{\mathcal{F}}$.*
(2) *For every Rabin embedding g of $\mathcal{F}$ (into any computable ACF $\mathcal{E}$), the image of g is a computable subset of $\mathcal{E}$ if and only if $\mathcal{F}$ has a splitting algorithm.*

So Part 1 implies that $\mathcal{F}$ can always be taken to be a c.e. subfield within some computable algebraic closure of itself. For algebraic number fields, we may fix this closure, but not for fields in general.

Corollary 12.

(1) *The computably presentable algebraic field extensions of $\mathbb{Q}$ are precisely the c.e. subfields of any single computable presentation of $\overline{\mathbb{Q}}$, even up to computable isomorphism.*
(2) *The computably presentable field extensions of $\mathbb{Q}$ of transcendence degree $\leq n$ are precisely the c.e. subfields of any single computable presentation of $\overline{\mathbb{Q}(X_1, \ldots, X_n)}$, again up to computable isomorphism.*
(3) *The computably presentable fields of characteristic 0 are precisely the c.e. subfields of all computable presentations of $\overline{\mathbb{Q}(X_1, X_2, \ldots)}$, up to computable isomorphism.*

The algebraic closure of any single field $\mathbb{Q}(X_1, \ldots, X_n)$, for any $n \geq 0$, is said to be *computably categorical*: every pair of computable presentations of this algebraic closure have a computable isomorphism between them. This is why, in (1) and (2), a single copy of the field suffices. On the other hand, the field in (3) is not computably categorical. In fact, since the purely transcendental extension $\mathbb{Q}(X_1, X_2, \ldots)$ has a computable presentation with a computable transcendence basis and a splitting algorithm, Rabin's Theorem implies the existence of a computable presentation C of the algebraic closure of this field with its own computable transcendence basis. One checks that then every c.e. subfield of C must then also have a computable transcendence basis. However, in [8] Metakides and Nerode constructed a computable field $\mathcal{F}$ with no computable transcendence basis, and so this $\mathcal{F}$ has no Rabin embedding g into C, since the preimage of a computable transcendence basis for $g(\mathcal{F})$ would be a computable transcendence basis for $\mathcal{F}$. Of course, by Theorem 11, $\mathcal{F}$ does have a Rabin embedding into a different computable ACF isomorphic to C. This suggests why the statement in (3) of Corollary 12 is not as strong as (1) and (2).

For the converse of each part of the corollary, notice that any c.e. subfield of any computable field with domain $\{a_0, a_1, \ldots\}$ can be pulled back to a domain $\{b_0, b_1, \ldots\}$ using an enumeration of the subfield, with the operations lifted from the subfield to its pullback. Since the pullback is computable, the lifted operations are also computable.

With Rabin's Theorem we may also answer a question posed above. This corollary nicely illustrates the usefulness of the theorem, since it is not at all easy to prove the answer directly. (A direct proof using symmetric polynomials appears in [3].)

Corollary 13. *A computable field $\mathcal{F}$ has a splitting algorithm if and only if it has a root algorithm.*

Proof. We discussed the forward direction earlier, but the converse should surprise the attentive reader: just because we know that a given polynomial in $\mathcal{F}[X]$, say of degree 26, has no roots in $\mathcal{F}$, how can we know whether it factors there? To see how, fix a Rabin embedding g of $\mathcal{F}$ into some computable algebraically closed $\overline{\mathcal{F}}$. Now for any $x \in \overline{\mathcal{F}}$, we may find some $p(X) \in \mathcal{F}[X]$, with image $\overline{p}(X) \in (g(\mathcal{F}))[X]$ under g, for which $\overline{p}(x) = 0$. We determine the roots of $p(X)$ in $\mathcal{F}$ by recursion, searching for a root r_{n+1} of $\frac{p(X)}{(X-r_1)\cdots(X-r_n)}$ in $\mathcal{F}$, starting with $n = 0$, until the root algorithm for $\mathcal{F}$ says that $\frac{p(X)}{(X-r_1)\cdots(X-r_n)}$ has no roots in $\mathcal{F}$. Then $x \in g(\mathcal{F})$ if and only if $x = g(r_i)$ for some $i \leq n$. Thus $g(\mathcal{F})$ is computable, and Rabin's Theorem yields a splitting algorithm for $\mathcal{F}$. □

We will also need the following theorem, from chapter 17 of the excellent reference [2] by Fried and Jarden. For deeper investigations into the Galois theory of computable fields, this result is essential.

Theorem 14. *Galois groups of Galois extensions of computable subfields of $\overline{\mathbb{Q}}$ are computable, uniformly in a splitting algorithm for the subfield and in any finite generating set of the extension within $\overline{\mathbb{Q}}$.*

Combined with Rabin's Theorem and classical Galois theory, this theorem yields a nice result for radical closures, a topic we will use in the next section.

Definition 15. For any subfield $\mathcal{E}$ of an algebraically closed field $\mathcal{F}$, the *radical closure* of $\mathcal{E}$ is the smallest subfield of $\mathcal{F}$ that contains $\mathcal{E}$ and, for every $n > 1$, contains n distinct n-th roots of each of its nonzero elements. $\mathcal{E}$ is *radically closed* if $\mathcal{E}$ is its own radical closure.

Of course, classical Galois theory shows that the radical closure can be a proper subfield of the algebraic closure, and specifically that certain polynomials of degree 5 fail to have roots in the radical closure.

Corollary 16. *Fix any computable field $\mathcal{F}$ with a splitting algorithm. Then the radical closure of $\mathcal{F}$ also has a computable presentation with a splitting algorithm, within which $\mathcal{F}$ is a computable subfield.*

Proof. Rabin's Theorem yields a Rabin embedding g of $\mathcal{F}$ into a computable algebraically closed field $\overline{\mathcal{F}}$ and shows that $g(\mathcal{F})$ is computable. For any $x \in \overline{\mathcal{F}}$, we can use the splitting algorithm for $\mathcal{F}$ to find an irreducible polynomial $p(X) \in \mathcal{F}[X]$ whose image under g has x as a root. The splitting field $\mathcal{F}_p \subset \overline{\mathcal{F}}$ of p over $g(\mathcal{F})$ is a finite extension of $g(\mathcal{F})$, hence also computable, and once we have found all roots of p in $\overline{\mathcal{F}}$, Theorem 14 then allows us to compute the (finite) Galois group G for $\mathcal{F}_p$ over $g(\mathcal{F})$, viewed as a permutation group on the roots of p. But now it is a well-known result of Galois theory that x lies in the radical closure of $g(\mathcal{F})$ if and only if G is solvable, and we may determine solvability of G simply by repeatedly computing commutator subgroups $G^{(m)}$ until either $G^{(m+1)} = G^{(m)}$ or $G^{(m)}$ is trivial.

This constitutes an algorithm for determining membership of an arbitrary $x \in \overline{\mathcal{F}}$ in the radical closure of $g(\mathcal{F})$ within $\overline{\mathcal{F}}$. By Corollary 12, the radical closure is itself computably presentable, via a computable isomorphism (under which the preimage of the computable subfield $g(\mathcal{F})$ is also computable), and has a splitting algorithm, by Rabin's Theorem. □

Effective Unsolvability of the Quintic

Finally we show that the famous Galois-theoretic result of unsolvability of the quintic equation by radicals also holds when "solvability" is taken to refer to algorithms for computable fields, as discussed above in the section "Algorithms and Galois Theory". Indeed, the field $\mathcal{E}$ we construct will be radically closed, with $R_n(\mathcal{E}) = \mathcal{E}$ for every n. So, as in the classical result, the unsolvability remains even when we are given the ability to find every radical we could want.

Theorem 17. *There exists a computable field $\mathcal{E}$ with $R_n(\mathcal{E}) = \mathcal{E}$ for every n, such that $P_5(\mathcal{E})$ is not computable.*

Proof. We start by fixing a single polynomial $p(X, Y)$ of degree 5 in Y, with rational coefficients, such that when p is viewed as a polynomial $p_X(Y)$ over the field $\mathbb{Q}(X)$, no root of p_X lies in the radical closure of $\mathbb{Q}(X)$, nor in the algebraic closure of $\mathbb{Q}$. An example is $p(X, Y) = XY^5 + Y^5 - Y - 1$, which can be shown using methods from Section 8.10 of [16] to have the symmetric group S_5 as its Galois group over $\mathbb{Q}(X)$.

(Details: we apply the result on p. 198 of [16] with $\mathfrak{R} = \mathbb{Q}[X]$ and $\mathfrak{p} = (X)$ to see that the Galois group of $p_X(Y)$ over $\mathbb{Q}(X)$ contains the Galois group of $(Y^5 - Y - 1)$ over $\mathbb{Q}$, which is shown on the following page in [16] to be S_5. Since S_5 is not solvable, no root of p_X lies in the radical closure of $\mathbb{Q}(X)$. Moreover, if $p_X(r) = 0$, then $(r^5X) + r^5 - r - 1 = 0$, and since X is transcendental over $\mathbb{Q}$, r cannot lie in $\overline{\mathbb{Q}}$.)

Now consider a computable field $\mathbb{Q}(X_0, X_1, \ldots)$, with computable transcendence basis $\{X_0, X_1, \ldots\}$. By Theorems 6 and 11, its algebraic closure has a computable presentation C, for which there exists a Rabin embedding g of $\mathbb{Q}(X_0, \ldots)$ into C with computable image. We define the polynomials $p_e(Y) = p(g(X_e), Y) \in C[Y]$, for every e.

We build a computably enumerable subfield $\mathcal{F} \subseteq C$, by enumerating a generating set W and closing under the field operations (including negation and reciprocals) and also under the operation of taking n-th roots, for every $n > 0$. To begin with, W contains all the elements X_i of the (computable) transcendence basis given above. (More precisely, W contains their images in C.) Then we computably enumerate the set K from Fact 3. For each new number e that appears in our enumeration of K, we search through C for the five roots of p_e and enumerate all those roots into W. Having done so, of course, we continue closing $\mathcal{F}$ under all the operations, including taking radicals. The subfield $\mathcal{F}$ is the set of all elements of C that either enter W at some stage, or are included in our closure process, so we have given a computable enumeration of $\mathcal{F}$.

Officially $\mathcal{F}$ itself is not a computable field, but we may use Corollary 12 to pull $\mathcal{F}$ back to a computable field $\mathcal{E}$ with a computable isomorphism g from $\mathcal{E}$ onto $\mathcal{F}$. Since we closed $\mathcal{F}$ under radicals, we have $R_n(\mathcal{F}) = \mathcal{F}$ for all n, and thus $R_n(\mathcal{E}) = \mathcal{E}$ as well. Similarly, if the set $P_5(\mathcal{E})$ were computable, then we could also compute whether an arbitrary $q(Y) \in \mathcal{F}[Y]$ lies in $P_5(\mathcal{F})$, just by checking whether its preimage lies in $P_5(\mathcal{E})$. (To get the preimage, just search for the preimages under g of the coefficients of q.)

Now we claim that each natural number e lies in K if and only if the polynomial p_e lies in $P_5(\mathcal{F})$. Since from e we can easily compute p_e, the computability of $P_5(\mathcal{F})$ would therefore imply computability of the noncomputable set K. First, if $e \in K$, then we enumerated a root of p_e into W, so $p_e \in P_5(\mathcal{F})$. Next suppose $e \notin K$, and let r_e be any root of p_e in C. Then X_e is algebraically dependent on r_e in C, and since $e \notin K$, r_e never entered W. Moreover, our choice of $p(X, Y)$ ensured that r_e cannot lie in the radical closure of $\mathbb{Q}(X_e)$, nor in $\overline{\mathbb{Q}}$. Therefore, if r_e ever entered $\mathcal{F}$ under our closure operations, it did so due to some roots $r_{i_1}, \ldots, r_{i_m} \in W$ from some polynomials p_{i_k}, with all $i_k \neq e$. But then r_e would sit in the algebraic closure of $\mathbb{Q}(X_{i_1}, \ldots, X_{i_m})$, contradicting the algebraic independence of X_e from the set $\{X_{i_1}, \ldots, X_{i_m}\}$. Thus no roots of p_e lie in $\mathcal{F}$, so $p_e \notin P_5(\mathcal{F})$. Therefore, as we claimed, $e \in K$ if and only if $p_e \in P_5(\mathcal{F})$, so $P_5(\mathcal{F})$ is not computable, and neither is $P_5(\mathcal{E})$. □

We invite the reader to attempt to prove Theorem 17 for algebraic field extensions of $\mathbb{Q}$. Of course, it is not necessary to have $R_n(\mathcal{E}) = \mathcal{E}$ for

all n, but one would like to have $R_n(\mathcal{E})$ be computable uniformly in n. That is, there should be a single algorithm that accepts a pair $\langle n, x\rangle$ as input and decides whether $x \in R_n(\mathcal{E})$. (The nonuniform version simply requires every set $R_n(\mathcal{E})$ to be computable, allowing a completely different algorithm for each n.)

Notes

The foregoing discussion in no way replaces classical Galois theory, of course. First of all, the results of the classical theory were necessary: they provided the polynomials whose roots all lie outside the radical closure of the field we built. Second, our results serve mainly to reinforce the classical conclusion that there is something special about the degree 5 for polynomials: the process of searching for roots runs into trouble when one reaches that degree. Finally, our discussion only applied to computable fields. These were sufficient to provide the example we wanted, in Theorem 17, but one would like to extend the discussion. Other countable fields can be considered if one relativizes the notion of computability to allow an oracle, and the results from preceding sections would generally carry over to that case. However, computable model theory has always restricted itself to countable structures, essentially because the nature of Turing machines and computations in finite time allows only countably many inputs to such a machine. The author is enthusiastic about his own current work on *locally computable structures*, i.e., mathematical structures, quite possibly uncountable, whose finitely generated substructures are all computably presentable in a uniform way. As work on this topic progresses, notions from this article might come to apply to many uncountable fields as well. Details are available in [10], and a brief summary appears in [9].

In this article, every time we have wanted to produce an example of noncomputability, we have used the set K. The reader should not be misled into thinking that K is the only noncomputable set available. Indeed, one can build infinitely many computably enumerable sets, no two of which are Turing-equivalent to each other (as defined on page 802), and beyond those, there are uncountably many subsets of $\mathbb{N}$ that are not computably enumerable and that have their own degrees. Much of computable model theory considers ways in which structures, e.g., fields, representing all these different degrees of complexity may be produced. For simplicity, we have avoided such questions here.

On the other hand, the search procedures used here may often seem irritatingly slow. Does one really need to search through $\mathbb{Q}$ element by element to find the solution to a polynomial equation? When one starts to consider questions about the amount of time and memory required for a search, one has crossed into theoretical computer science, where such questions are studied intensely and where simple, slow search procedures as in this article are deemed useless. In contrast, computability theorists wish to consider all possible algorithms, and the easiest way to do so is to strip away their complexity and reduce them all to search procedures. Having done so, one can readily produce noncomputable objects, by ensuring that no search procedure works. It has been said that the discipline should really be called *noncomputability theory*, since it puts so much effort into building and studying noncomputable objects. However, such a name would be not only unduly negative, but also inaccurate: even when studying noncomputable objects, we are usually asking which objects contain enough information to compute other objects (i.e., which objects have higher Turing degree), so the real subject is still computability.

The results in this article should be assumed to be folklore unless specific attribution is made. Some of the questions considered may not have been raised before, but by the standards of hard-core computable model theory, the answers given are not particularly complex. The author would be grateful for any information about sources that may already have considered material related to Lemma 8, Corollary 9, or Theorem 17.

Many thanks are due to Phyllis Cassidy, Richard Churchill, Li Guo, William Keigher, Jerry Kovacic, and William Sit, the organizers of the the Second International Workshop on Differential Algebra and Related Topics, who invited the author to give a tutorial there on April 12, 2007. This article grew out of that presentation, with the encouragement of Andy Magid. The reference [9], by the same author, uses the same notation and terminology and provides a fair amount of complementary information, for those wishing to see more.

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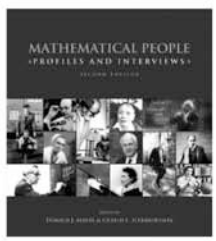

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Donaldson Receives Nemmers Prize

Photo courtesy of Imperial College London.

Simon Donaldson

Northwestern University has announced that SIMON DONALDSON is the recipient of the 2008 Nemmers Prize in Mathematics, believed to be the largest monetary award in the United States for outstanding achievements in the discipline. Awarded to scholars who made major contributions to new knowledge or the development of significant new modes of analysis, the prize carries a US$150,000 stipend.

Donaldson, Royal Society Research Professor at Imperial College, London, received the Frederic Esser Nemmers Prize in Mathematics for his "groundbreaking work in four-dimensional topology, symplectic geometry and gauge theory, and for his remarkable use of ideas from physics to advance pure mathematics." In connection with this award, Donaldson is scheduled to deliver public lectures and participate in other scholarly activities at Northwestern during the 2008–09 and 2009–10 academic years.

Donaldson received his B.A at Cambridge University and his D.Phil. from Oxford University. In 1986, only three years after completion of his doctorate, he was elected a fellow of the Royal Society, London. That same year he received the Fields Medal, widely recognized as the most prestigious honor for a mathematician under the age of 40. He was awarded the Royal Medal of the Royal Society in 1992, the Crafoord Prize in 1994, and the King Faisal Prize in 2006. In 2000 he was elected a foreign associate of the National Academy of Sciences.

"Donaldson's breakthrough work developed new techniques in the geometry of four-manifolds and the study of their smooth structures," said John Franks, professor and chair of mathematics at Northwestern. "His methods have been described as extremely subtle, using difficult nonlinear partial differential equations. Using instantons, solutions to the equations of Yang-Mills gauge theory, he gained important insight into the structure of closed four-manifolds. Gauge theory techniques also enabled him to show the existence of four-manifolds with no smooth structure and others with infinitely many. His work has provided the seminal steps for the work of others in the study of four-manifolds." More recently, Donaldson has made fundamental contributions to the understanding of symplectic manifolds, the phase-spaces of classical mechanics, and he shows that a surprisingly large part of the theory of algebraic geometry extends to them. His two books and more than 60 published papers are widely recognized for their originality as well as their elegance and clarity.

Northwestern University also announced that Paul R. Milgrom, the Shirley R. and Leonard W. Ely Jr. Professor of Humanities and Sciences at Stanford University, has been awarded the Erwin Plein Nemmers Prize in Economics, which also carries a US$150,000 stipend.

The Nemmers Prizes are made possible through bequests from the late Erwin E. Nemmers, a former member of the Northwestern University faculty, and his brother, the late Frederic E. Nemmers, both of Milwaukee. The prizes are awarded every other year. Previous mathematicians to receive the prizes have been Yuri I. Manin (1994), Joseph B. Keller (1996), John H. Conway (1998), Robert J. Aumann (1998), Edward Witten (2000), Yakov G. Sinai (2002), Mikhael Gromov (2004), and Robert P. Langlands (2006).

Consistent with the terms of the Nemmers bequests, the Erwin Plein Nemmers Prize in Economics (named in honor of the Nemmers' father) and the Frederic Esser Nemmers Prize in Mathematics (named by Erwin in honor of his brother) are designed to recognize "work of lasting significance" in the respective disciplines.

—From a Northwestern University news release

Mathematical Sciences in the FY 2009 Budget

Samuel M. Rankin III

Highlights

• Federal support for the mathematical sciences is slated to grow from an estimated US$468.59 million in FY 2008 to an estimated US$516.8 million in FY 2009, an increase of 10.3 percent.

• The National Science Foundation's (NSF) Division of Mathematical Sciences (DMS) budget would increase by 16.0 percent to US$245.70 million.

• The aggregate funding for the mathematical sciences in the Department of Defense (DOD) agencies Air Force Office of Scientific Research (AFOSR), Army Research Office (ARO), Defense Advanced Research Project Agency (DARPA), National Security Agency (NSA), and Office of Naval Research (ONR)) would increase by 7.0 percent.

• Aggregate funding for the mathematical sciences in the Department of Energy (DOE) would increase by 9.4 percent to US$95.3 million.

Introduction

Research in the mathematical sciences is funded primarily through the National Science Foundation, the Department of Defense (including the National Security Agency), the Department of Energy, and the National Institutes of Health (NIH). As in previous years, the majority of federal support for the mathematical sciences in FY 2009 would come from the NSF, contributing approximately 47.5 percent of the federal total. The DOD accounts for around 17.9 percent of the total, with the NIH supplying 16.1 percent, and the DOE around 18.4 percent. The NSF currently accounts for nearly 70 percent of the federal support for academic research in the mathematical sciences and is the only agency that supports mathematics research broadly across all fields. The DOD, DOE, and NIH support research in the mathematical sciences that contributes to the missions of these agencies.

The DOD supports mathematical sciences research and related activities in several programs: the Directorates of Mathematics, Information, and Life Sciences and Physics and Electronics, within the AFOSR; the Mathematical and Information Sciences Division within the ARO; the Mathematics, Computers, and Information Sciences Research division within the ONR; the Defense Sciences Program and the Microsystems Technology Office within DARPA; and the Mathematical Sciences Program within the NSA.

The DOE funds mathematics through its Applied Mathematics and Scientific Discovery through Advanced Computing (SciDAC) programs within the DOE office of Advanced Scientific Computing Research. The National Institutes of Health funds mathematical sciences research primarily through the National Institute of General Medical Sciences (NIGMS) and through the National Institute of Biomedical Imaging and Bioengineering (NIBIB).

Trends in Federal Support for the Mathematical Sciences

The FY 2009 estimated aggregate spending for mathematical sciences research and related activities would be US$516.8 million, a potential increase of 10.3 percent over FY 2008 estimated spending. The NSF Division of Mathematical Sciences budget would increase by 16.0 percent in FY 2009, while the DOD agencies would increase by 7.0 percent for FY 2009. The AFOSR increases its mathematical sciences spending by 24.2 percent while the ARO mathematics budget decreases by 2.5 percent. The mathematical sciences budgets of the remaining

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This article is a slightly revised version of a chapter about federal funding in the mathematical sciences in AAAS Report XXXIII, Research & Development FY 2009, *published by the American Association for the Advancement of Science. The report is available on the Web at* http://www.aaas.org/spp/rd/.

DOD agencies would not grow in FY 2009. The DOE mathematical sciences budget increases by 9.4 percent while NIH funding is flat.

The mathematical sciences make major contributions to the country's intellectual capacity and are enabling technologies, which provide the tools, insight, and capability needed for innovation and technological progress. Many disciplines depend on discoveries in the mathematical sciences to open up new frontiers and advance discovery. Even so, many mathematical scientists who are performing excellent research and who submit grant proposals deemed of very high quality, are consistently either not funded or are under-funded. According to the Science and Engineering Indicators, 2008 Edition, in FY 2006, only 34.6 percent of full-time mathematics faculty, having doctoral degrees, received federal research support. This is much lower than most other fields of science.

National Science Foundation (NSF)

The Division of Mathematical Sciences (DMS), http://www.nsf.gov/div/index.jsp?div=DMS, is housed in the NSF Directorate of the Mathematical and Physical Sciences (MPS). This directorate also contains the Divisions of Astronomical Sciences, Chemistry, Materials Research, Physics, and Multidisciplinary Activities. The DMS supports advances in the intellectual frontiers of the mathematical sciences and enables the advance of knowledge in other scientific and engineering fields.

The DMS has essentially two modes of support: research and education grants, and institutes. Grants include individual-investigator awards; awards for multidisciplinary groups of researchers; and educational and training awards aimed at increasing the number of U.S. students choosing careers in the mathematical sciences. The DMS provides core support for five mathematical sciences research institutes, as well as major support for three other institutes. These institutes, funded on a competitive basis, serve to develop new ideas and directions in the mathematical sciences, as well as to promote interaction with other disciplines.

In FY 2009 approximately 61 percent of the DMS budget will be available for new research awards, with the remainder going to continuing commitments from previous years. The DMS FY

Table 1: Federal Funding for the Mathematical Sciences (millions of dollars)#

	FY 07 Actual	FY 08 Estimate	FY 09 Request	Change 2008–09 Amount	Change 2008–09 Percent
National Science Foundation					
DMS	205.74	211.79	245.70	33.91	16.0%
Department of Defense					
AFOSR	34.9	38.4	47.7	9.3	24.2
ARO	14.0	12.0	11.7	-0.3	-2.5
DARPA	26.4	18.6	15.7	-2.9	-15.6
NSA	4.0	4.0	4.0	0.0	0.0
ONR*	13.6	13.6	13.6	0.0	0.0
Total DOD	92.9	86.6	92.7	6.1	7.0
Department of Energy					
Applied Mathematics	32.8	36.9	43.2	6.3	17.1
SciDAC**	41.7	50.2	52.1	1.9	3.8
Total DOE	74.5	87.1	95.3	8.2	9.4
National Institutes of Health					
NIGMS*	45.0	45.0	45.0	0.0	0.0
NIBIB*	38.1	38.1	38.1	0.0	0.0
Total NIH	83.1	83.1	83.1	0.0	0.0
Total All Agencies	456.24	468.59	516.8	48.21	10.3

#*Budget information is derived from agency documents and conversations with agency program managers and representatives.*

**Estimates.*

***Scientific Discovery through Advanced Computing (SciDAC).*

2009 priorities are fundamental mathematical and statistical science, including activities that strengthen the core of the discipline and enable effective partnering with other science and engineering disciplines; and interdisciplinary research and education, including key components of the American Competitiveness Initiative (ACI) where the mathematical sciences play a critical role in discovery for competitiveness and innovation. These ACI components are NSF-wide initiatives, Cyber-enabled Discovery and Innovation (CDI), Science Beyond Moore's Law, and Adaptive Systems Technologies; MPS initiatives, Quantum Information Sciences, MPS-Life Sciences Interface, and ACI Fellows.

The ACI Fellows program aims to improve the freshman and sophomore experience in mathematics through involvement in interdisciplinary, discovery-based activities. The program hopes to help increase the number of undergraduate mathematics, science, and engineering majors. The goal of the MPS-Life Sciences Interface is to promote the emergence of biology as a quantitative science and encourage bio-technological innovation. Adaptive Systems Technologies will focus on innovation in areas such as robotics, sensor systems, specialized materials, and assistive devices. Quantum Information Sciences (QIS) involves research on quantum computing and communications, including the understanding and implementation of algorithms for QIS.

The DMS is slated to receive a budget of US$245.70 million in FY 2009, an increase of US$33.91million or 16.0 percent over the FY 2008 budget estimate. The US$33.91 million is broken down as follows: US$20.81 million increase for core programs; US$5.20 million increase for Cyber-enabled Discovery and Innovation; US$1.75 million for Science Beyond Moore's Law; US$2.0 million for Quantum Information Sciences; US$1.0 million for MPS-Life Sciences Interface; US$0.50 million for Adaptive Systems Technologies; US$2.0 million for ACI Fellows; and a US$2.0 million increase for early careers investigators. The DMS budget increases by 16.0 percent over FY 2008.

Air Force Office of Scientific Research (AFOSR)

Funding for the mathematical sciences at AFOSR is found in the Directorate of Mathematics, Information, and Life Sciences and the Directorate of Physics and Electronics. The AFOSR mathematics program includes specific portfolios in dynamics and control, physical mathematics and applied analysis, computational mathematics, optimization and discrete mathematics, electromagnetics, and sensing, surveillance, and navigation. For additional information on the focus areas within each of these portfolios, please refer to the Broad Area Announcement 2008-1 which can be viewed on the AFOSR public website at http://www.afosr.af.mil. The AFOSR FY 2009 budget for the mathematical sciences would increase by 24.2 percent over FY 2008.

Army Research Office (ARO)

The Mathematics Program, housed in the Mathematical and Information Sciences Division, http://www.arl.army.mil/main/main/default.cfm?Action=29&Page=194, manages the following programs: modeling of complex systems; computational mathematics; discrete mathematics and computer science; probability and statistics and stochastic analysis; and cooperative systems. The Mathematical Sciences Division plays an essential role in the modeling, analysis, and control of complex phenomena and large-scale systems which are of critical interest to the Army. The areas of application include communication networks, image analysis, visualization and synthetic environments, pattern recognition, test and evaluation of new systems, sensor networks, network science, robotics, and autonomous systems. The division also works closely with the Computer and Information Sciences Division of ARO to develop mathematical theory for systems control, information processing, information assurance, network design, and data fusion. The ARO budget for the mathematical sciences would decrease by 2.5 percent from FY 2008.

Defense Advanced Research Projects Agency (DARPA)

The Defense Sciences Office (DSO) and the Microsystems Technology Office (MTO) inside DARPA both have mathematics programs cutting across mathematics and its applications. Current program areas include: Analog-to-Information, Cognitively Augmented Design for Quantum Technology, Discovery and Exploitation of Structure in Algorithms, Femtosecond Adaptive Spectroscopy Techniques for Remote Agent Detection, Focus Areas in Theoretical Mathematics, Fundamental Laws of Biology, Mathematical Time Reversal, Multiple Optical Nonredundant Aperture Generalized Sensors, Non-Linear Mathematics for Mixed Signal Microsystems, Predicting Real Optimized Materials, Protein Design Processes, Robust Uncertainty Management, Sensor Topology and Minimal Planning, Space-Time Adaptive Processing, and Topological Data Analysis. DARPA has also announced an open BAA on twenty-three Mathematical Challenges. Further details can be found at http://www.darpa.mil/dso/personnel/mann.htm and http://www.darpa.mil/MTO/personnel/healy_d.html. Aggregate funding for the mathematical sciences decreases by 15.6 percent from FY 2008.

Department of Energy (DOE)

Mathematics at DOE is funded through the Office of Advanced Scientific Computing Research (ASCR), http://www.science.doe.gov/ascr/, one of six interdisciplinary research offices within DOE's Office of Science. Research supported by ASCR underpins computational science throughout

DOE. ASCR funding for the mathematical sciences is found primarily in the Applied Mathematics program and the Scientific Discovery through Advanced Computing (SciDAC) program. The Applied Mathematics program supports research on the mathematical methods and numerical algorithms that enable the effective description, understanding, and prediction of complex physical, biological, and engineered systems. Subjects of current interest include numerical methods for the parallel solution of systems of partial differential equations, large-scale linear and nonlinear systems, and large-scale parameter-estimation problems; analytical and numerical techniques for modeling complex physical and biological phenomena, such as fluid turbulence and microbial populations; analytical and numerical methods for bridging a broad range of temporal and spatial scales; and optimization, control, and risk analysis of complex systems such as computer networks and electrical power grids. The FY 2009 Applied Mathematics program budget will support a new joint Applied Mathematics-Computer Science Institute to focus on the challenges of computing at extreme scales that blur the boundaries between these disciplines; a new effort in the mathematics of extremely large datasets to address the most fundamental issues in finding the key features, understanding the relationships among those features, and extracting scientific insights from them; and increases in key areas of long-term research most relevant to meeting the challenges of computing at extreme scales and risk assessment in complex systems. In FY 2009, the SciDAC program will support seventeen Science Application Partnerships, nine Centers for Enabling Technologies, and four SciDAC Institutes that were competitively selected in FY 2006. Applied mathematics plays a fundamental role throughout the Science Application Partnerships and is the principal focus of three Centers for Enabling Technology and one SciDAC Institute. Aggregate funding for the mathematical sciences would increase by 9.4 percent over FY 2008.

National Institutes of Health (NIH)

The NIH funds mathematical sciences research through the National Institute of General Medical Sciences (NIGMS) and the National Institute of Biomedical Imaging and Bioengineering (NIBIB). Mathematical sciences areas of interest are those that support the missions of NIGMS and NIBIB. Currently, NIGMS is supporting a biomathematics initiative at around US$12 million per year in cooperation with the National Science Foundation, and NIBIB is participating in a joint initiative with the NSF and other NIH institutes, "Collaborative Research in Computational Neuroscience". The aggregate budget for the mathematical sciences in NIBIB and NIGMS is unchanged from FY 2008.

National Security Agency (NSA)

The Mathematical Sciences Program of the NSA administers a Grants Program that supports fundamental research in the areas of algebra, number theory, discrete mathematics, probability, and statistics. The Grants Program also accepts proposals for conferences and workshops in these research areas. In addition to grants, the Mathematical Sciences Program supports an in-house faculty Sabbatical Program. The program administrators are especially interested in funding initiatives that encourage the participation of underrepresented groups in mathematics (such as women, African-Americans, and other minorities). NSA is the largest employer of mathematicians in the United States. As such, it has a vested interest in maintaining a healthy academic mathematics community in the United States. For more information, see the website `http://www.nsa.gov/msp/index.cfm`. The NSA mathematics budget would remain unchanged from FY 2008.

Office of Naval Research (ONR)

The ONR Mathematics, Computers, and Information Research Division's scientific objective is to establish rigorous mathematical foundations and analytical and computational methods that enhance understanding of complex phenomena, and enable prediction and control for Naval applications in the future. Basic research in the mathematical sciences is focused on analysis and computation for multi-phase, multi-material, multi-physics problems; predictability of models for nonlinear dynamics; electromagnetic and acoustic wave propagation; signal and image analysis and understanding; modeling pathological behaviors of large, dynamic complex networks and exploiting hybrid control to achieve reliability and security; optimization; and formal methods for verifiably correct software construction. For more information see the website, `http://www.onr.navy.mil/sci_tech/31/311/default.asp`. The Mathematical, Computer, and Information Sciences Division's budget would remain unchanged from FY 2008.

Note: Information gathered from agency documents and from agency representatives.

About the Cover

Floating Bodies

This month's cover shows two views of a group of diagrams to be found in the Archimedes Palimpsest. It accompanies the article by Shirely Gray in this issue in which the Palimpsest is discussed. In the next issue of the *Notices* there will be a review by Len Berggren of *The Archimedes Codex,* a book by Will Noel and Reviel Netz about the Palimpsest. The images have been taken from the Palimpsest's website `http://www.archimedespalimpsest.org/`.

A palimpsest is a manuscript in which an older and presumably no longer wanted text has been erased in order to write over it. In this case, it happens that the text that has been overwritten is the oldest and most authentic version of several of the works of Archimedes, and in the modern perspective far more valuable than the Byzantine religious script laid on top. On the left you can see the visible prayer book, and on the right what technology has been able to extract.

The diagrams are from the end of Archimedes' treatise "On Floating Bodies I". It justifies easily the frequent attribution to Archimedes of being the first theoretical physicist. The treatise opens with what is essentially a technical lemma characterizing spheres, and then goes on (in Heath's translation):

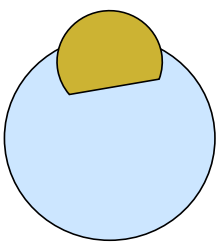
> Proposition 2. *The surface of any fluid at rest is the surface of a sphere whose centre is the same as that of the earth.*

Since Eratosthenes was a contemporary of Archimedes, indeed a correspondent, the assumption implicit here should be no surprise, but since Archimedes' work must have been familar to European navigators of the fifteenthth century, one might justifiably wonder why we were all told the myth of Columbus—but that's another story.

The diagram on the cover is part of the ninth and last proposition of "Floating Bodies I". In T. L. Heath's translation:

> Proposition 9. *If a solid in the form of a segment of a sphere, and of a substance lighter than a fluid, be immersed in it so that its base is completely below the surface, the solid will rest in such a position that its axis is perpendicular to the surface.*

A segment of a sphere is one of the pieces into which it is sliced by a plane, so the situation is roughly like this (with the immersed body shown in an unstable state):



Heath goes on to remark:

> The proof of this Proposition has only survived in a mutilated form. It deals moreover with only one case out of three which are distinguished in the beginning, viz. that in which the segment is greater than a hemisphere…

Thus we might hope to recover from the Palimpsest a somewhat more complete version of "Floating Bodies". The diagram on the cover does not reassure us, however. Reviel Netz, coauthor of the book reviewed by Berggren, tells us tentatively:

> The original text for I.9 as transmitted in late antiquity had only one case … therefore had only one figure. The immediate source of the Palimpsest (perhaps some text of Late Antiquity?), as well as the Medieval translator, both thought that the text should be accompanied by three figures, not one. The immediate source of the Palimpsest solved this problem clumsily, adapting the figures of I.8 as if they could fit exactly the cases of I.9. …
>
> What the evidence suggests … is that the original text had one figure only and that the latter figures are Medieval. Note that had we had only the Latin translation, we could well be led to believe that its latter figures are authorial: the divergence between the Palimpsest and the Latin translation is therefore telling and very important. In this way, even misleading, spurious figures can inform us of the original text of Archimedes—by allowing us to discount evidence which otherwise would appear significant.

He adds, "It's a devilish textual matter, Floating Bodies."

Nigel Wilson and Netz are working on the texts of the Palimpsest, hoping to publish in the not too distant future. In the meantime, Wilson has had privately printed, typeset by hand at the Jericho Press, a handsome if brief transcription of what the Palimpsest contains of the early part of "Floating Bodies I" (from the very early folia of the manuscript, which were extraordinarily difficult to render readable). Information about this curious booklet is available from J. F. Coakley at the Jericho Press (`jfc39@cam.ac.uk`).

The Palimpsest website contains much of great interest, in particular a very large collection of images. The copyright to all images of the manuscript belongs to the anonymous Owner of the Palimpsest, but they are freely usable, subject only to mention of this copyright. We can only hope that this kind of generosity be imitated widely.

—Bill Casselman, Graphics Editor
(`notices-covers@ams.org`*)*

2007 Annual Survey of the Mathematical Sciences in the United States

(Second Report)

Updated Report on the 2006–2007 Doctoral Recipients Starting Salary Survey of the 2006–2007 Doctoral Recipients

Polly Phipps, James W. Maxwell, and Colleen A. Rose

Update on the 2006–2007 Doctoral Recipients

This Second Report of the 2007 Annual Survey gives an update of the 2006–2007 new doctoral recipients from the First Report, which appeared in the *Notices of the AMS* in February 2008, pages 253–63. The First Report contains a section on new doctoral recipients in statistics that is not updated here.

The 2007 Annual Survey represents the fifty-first in an annual series begun in 1957 by the American Mathematical Society. The 2007 Survey is under the direction of the Data Committee, a joint committee of the American Mathematical Society, the American Statistical Association, the Institute of Mathematical Statistics, the Mathematical Association of America, and the Society of Industrial and Applied Mathematics. The current members of this committee are Richard Cleary, Amy Cohen-Corwin, Richard M. Dudley, John W. Hagood, Abbe H. Herzig, Donald R. King, David J. Lutzer, James W. Maxwell (ex officio), Bart Ng, Polly Phipps (chair), David E. Rohrlich, and Henry Schenck. The committee is assisted by AMS survey analyst Colleen A. Rose. Comments or suggestions regarding this Survey Report may be directed to the committee.

Introduction

The Annual Survey of the Mathematical Sciences collects information each year about degree recipients, departments, faculties, and students in the mathematical sciences at four-year colleges and universities in the United States. Information about recipients of doctoral degrees awarded between July 1, 2006, and June 30, 2007, was collected from doctorate-granting departments beginning in late spring 2007. The "2007 Annual Survey First Report" (*Notices*, February 2008, pages 253–63) presented survey results about 1,157 new doctoral recipients based on the data provided by the departments. Here we update this information using data obtained from 547 new doctoral recipients who responded to a questionnaire, "Employment Experiences of New Doctoral Recipients" (EENDR), sent in early October 2007 to all new doctoral recipients. In addition, this report incorporates information on an additional 176 doctoral recipients from departments that responded too late to have the information included in the First Report. Finally, we present the starting salaries and other employment information from the new doctoral recipients that responded to the EENDR questionnaire.

The names and thesis titles of the 2006–2007 doctoral recipients reported on in the First Report were published in "Doctoral Degrees Conferred" (*Notices*, February 2008, pages 280–99). A supplemental listing of the 176 additional new doctoral recipients appears at the end of this report on pages 826–830.

Doctorates Granted Departmental Response Rates (updated April 2007)

Group I (Pu)[1]	25 of 25 including	0 with no degrees
Group I (Pr)	20 of 23 including	0 with no degrees
Group II	52 of 56 including	1 with no degrees
Group III	64 of 75 including	16 with no degrees
Group IV	70 of 88 including	8 with no degrees
Group Va	21 of 21 including	1 with no degrees

[1] For definitions of groups see page 825.

Polly Phipps is a senior research statistician with the Bureau of Labor Statistics. James W. Maxwell is AMS associate executive director for special projects. Colleen A. Rose is AMS survey analyst.

Highlights

There were 1,333 doctoral recipients from U.S. institutions for 2006–2007, up 22 (2%) from the previous year, continuing an upward trend that began in 2002–2003. This is the highest number of new Ph.D.'s ever reported, and it would have been even larger but for the increased number of nonresponding departments. Of the 242 departments that responded in both 2006 and 2007 the number of degrees awarded increased from 1,216 to 1,307, a 7.5% increase.

The final unemployment rate was 2.4% for all 2006–2007 doctoral recipients and 1.5% for females, the lowest percentages reported since the early 1990's.

The number of new doctoral recipients who are not U.S. citizens is 757, down 2 from last year's number, but up 219 (41%) from 2002–2003.

The number of new doctoral recipients who are U.S. citizens is 576, up 24 (4%) from last year's number and 77 (15%) from 2002–2003. This is the highest number of U.S. citizens reported over the past ten surveys. The percentage of U.S. citizens among all doctoral recipients is 43%, up from 42% last year.

Females totaled 446 (33%) of all new doctoral recipients, up in number and percentage from 422 (32%) last year. The highest percentage of females among the annual counts of doctoral recipients was 34%, reported for 1998–1999. Of the 576 U.S. citizen new doctoral recipients, 180 are female (31%), up in number and percent from last year.

Of the 576 U.S. citizen new doctoral recipients this year, 6% are underrepresented minorities compared to 8% last year.

Of the 1,190 new doctoral recipients whose employment status is known, 1,151 reported having employment in fall 2007, with 88% (1,012) finding employment in the U.S. compared with 87% last year. Non-U.S. citizens accounted for 52% of those employed in the U.S. (last year this percentage was 58%).

The number of new doctoral recipients hired into U.S. academic positions in fall 2007 is 756. This is the highest such number reported over the past twenty-six years. Indeed, each of the numbers reported for the past three falls exceeds any number reported during the period from fall 1982 through fall 2003.

The number of new doctoral recipients taking positions in U.S. business/industry and government was 256 in fall 2007, a 5% increase from last year's numbers. This group constitutes 25% of all the new doctoral recipients employed in the U.S., the same percentage as last year.

There were 547 new doctoral recipients responding to the EENDR survey; of the 486 who found employment in the U.S., 53% reported obtaining a permanent position (up from 51% in fall 2006).

The percentage of temporarily employed respondents who reported taking a postdoctoral position in the U.S. decreased from 209 (76%) in fall 2006 to 172 (76%) in fall 2007.

Table 1A: Doctoral Recipients: Fall and Final Counts

Year	Fall	Final
1997–1998	1163	1176
1998–1999	1133	1135
1999–2000	1119	1127
2000–2001	1008	1065
2001–2002	948	960
2002–2003	1017	1037
2003–2004	1041	1081
2004–2005	1116	1222
2005–2006	1245	1311
2006–2007	1157	1333

Table 1B: Doctoral Recipients: Citizenship

Year	U.S.	Non-U.S.	TOTAL
2002–2003	499	538	**1037**
2003–2004	459	622	**1081**
2004–2005	496	726	**1222**
2005–2006	552	759	**1311**
2006–2007	576	757	**1333**

Table 1C: Doctoral Recipients by Type of Degree-Granting Department

	Department Group[1]					
	I (Pu)	I (Pr)	II	III	IV	Va
Number	322	141	264	152	357	97
Percent	24%	11%	20%	11%	27%	7%

[1] For definitions of groups see page 825.

Table 1D: Doctoral Recipients: U.S. Citizens—Percent Female and Percent Underrepresented Minorities

Year	U.S.	% Female	% URM*
1997–1998	537	29%	5%
1998–1999	560	34%	5%
1999–2000	566	29%	5%
2000–2001	532	31%	7%
2001–2002	428	30%	6%
2002–2003	499	32%	6%
2003–2004	459	33%	7%
2004–2005	496	28%	7%
2005–2006	552	28%	8%
2006–2007	576	31%	6%

* Percentage of underrepresented minorities calculated using Sex, Race/Ethnicity and Citizenship data gathered from granting departments.

Table 2A: Fall 2007 Employment Status of 2006–2007 Doctoral Recipients by Field of Thesis (updated April 2008)

TYPE OF EMPLOYER		FIELD OF THESIS												TOTAL
		Algebra Number Theory	Real, Comp., Funct., & Harmonic Analysis	Geometry/ Topology	Discr. Math./ Combin./ Logic/ Comp. Sci.	Probability	Statistics/ Biostat.	Applied Math.	Numerical Analysis/ Approxi-mations	Linear Nonlinear Optim./ Control	Differential, Integral, & Difference Equations	Math. Educ.	Other/ Unknown	
Group I (Public)[1]		23	14	17	7	5	4	11	2	0	9	0	1	**93**
Group I (Private)		21	4	17	3	0	2	4	5	0	8	0	0	**64**
Group II		16	9	10	8	1	4	10	9	1	10	0	1	**79**
Group III		8	4	4	3	2	15	5	2	1	3	2	1	**50**
Group IV		1	1	0	0	2	32	3	2	0	3	0	0	**44**
Group Va		0	0	1	4	0	0	2	4	0	4	0	0	**15**
Master's		11	10	9	7	1	22	6	5	3	6	6	0	**86**
Bachelor's		32	17	18	15	4	14	16	9	1	13	4	0	**143**
Two-Year College		5	1	1	1	2	1	3	1	0	1	0	0	**16**
Other Academic Dept.[2]		6	6	3	5	0	68	18	8	0	5	2	2	**123**
Research Institute/ Other Nonprofit		3	0	3	1	1	21	8	3	1	2	0	0	**43**
Government		3	1	2	2	1	10	7	4	0	2	0	0	**32**
Business and Industry		8	2	6	19	17	130	17	11	5	7	0	2	**224**
Non-U.S. Academic		34	8	14	11	4	21	12	2	3	19	1	0	**129**
Non-U.S. Nonacademic		1	0	1	1	1	3	0	2	1	0	0	0	**10**
Not Seeking Employment		3	1	0	0	0	3	2	0	0	1	1	0	**11**
Still Seeking Employment		6	2	2	3	0	11	2	2	0	0	0	0	**28**
Unknown (U.S.)		6	9	6	4	2	18	9	3	2	2	2	1	**64**
Unknown (non-U.S.)[3]		6	5	6	6	3	31	8	4	3	6	1	0	**79**
TOTAL		**193**	**94**	**120**	**100**	**46**	**410**	**143**	**78**	**21**	**101**	**19**	**8**	**1333**
Column Subtotals	Male	145	65	94	68	34	215	111	53	14	75	8	5	**887**
	Female	48	29	26	32	12	195	32	25	7	26	11	3	**446**

[1] For definitions of groups see page 825.
[2] These are departments outside the mathematical sciences.
[3] Includes those whose status is reported as "unknown" or "still seeking employment".

Table 2B: Fall 2007 Employment Status of 2006–2007 Doctoral Recipients by Type of Degree-Granting Department (updated April 2008)

TYPE OF EMPLOYER		TYPE OF DOCTORAL DEGREE-GRANTING DEPARTMENT						TOTAL	Row Subtotals	
		Group I (Public)	Group I (Private)	Group II Math.	Group III Math.	Group IV Statistics	Group Va Applied Math.		Male	Female
Group I (Public)[1]		50	22	9	2	3	7	**93**	74	19
Group I (Private)		33	19	6	0	2	4	**64**	47	17
Group II		25	12	31	5	4	2	**79**	56	23
Group III		8	2	13	18	6	3	**50**	30	20
Group IV		4	1	4	1	33	1	**44**	24	20
Group Va		5	0	0	1	0	9	**15**	10	5
Master's		16	4	35	18	13	0	**86**	50	36
Bachelor's		35	9	57	35	4	3	**143**	89	54
Two-Year College		3	0	6	4	0	3	**16**	10	6
Other Academic Dept.[2]		9	13	16	11	66	8	**123**	76	47
Research Institute/ Other Nonprofit		3	9	4	0	20	7	**43**	26	17
Government		8	1	4	5	8	6	**32**	24	8
Business and Industry		42	11	16	22	115	18	**224**	142	82
Non-U.S. Academic		42	23	28	5	23	8	**129**	100	29
Non-U.S. Nonacademic		2	3	0	0	3	2	**10**	10	0
Not Seeking Employment		1	2	3	2	3	0	**11**	5	6
Still Seeking Employment		4	1	6	6	6	5	**28**	22	6
Unknown (U.S.)		15	5	16	9	18	1	**64**	42	22
Unknown (non-U.S.)[3]		17	4	10	8	30	10	**79**	50	29
TOTAL		**322**	**141**	**264**	**152**	**357**	**97**	**1333**	**887**	**446**
Column Subtotals	Male	240	106	185	99	182	75	**887**		
	Female	82	35	79	53	175	22	**446**		

[1] For definitions of groups see page 825.
[2] These are departments outside the mathematical sciences.
[3] Includes those whose status is reported as "unknown" or "still seeking employment".

Table 2C: Degree-Granting Department of 2006–2007 Doctoral Recipients by Field of Thesis (updated April 2008)

TYPE OF DOCTORAL DEGREE-GRANTING DEPARTMENT	FIELD OF THESIS												TOTAL
	Algebra Number Theory	Real, Comp., Funct., & Harmonic Analysis	Geometry/ Topology	Discr. Math./ Combin./ Logic/ Comp. Sci.	Probability	Statistics/ Biostat.	Applied Math.	Numerical Analysis/ Approxi-mations	Linear Nonlinear Optim./ Control	Differential, Integral, & Difference Equations	Math. Educ.	Other/ Unknown	
Group I (Public)[1]	89	28	41	39	12	11	38	17	5	40	0	2	**322**
Group I (Private)	42	8	36	12	9	3	12	4	1	14	0	0	**141**
Group II	50	30	38	15	14	9	46	25	5	21	8	3	**264**
Group III	9	16	3	17	5	43	17	10	4	16	11	1	**152**
Group IV	0	12	0	0	2	333	6	2	1	0	0	1	**357**
Group Va	3	0	2	17	4	11	24	20	5	10	0	1	**97**
TOTAL	**193**	**94**	**120**	**100**	**46**	**410**	**143**	**78**	**21**	**101**	**19**	**8**	**1333**

[1] For definitions of groups see page 825.

Table 2D: Percentage of Employed New Doctoral Recipients by Type of Employer

	Employed in U.S.		Employed outside. U.S.		NUMBER EMPLOYED
	Academic[1]	Nonacademic	Academic	Nonacademic	
Fall 2003	70%	17%	12%	2%	**792**
Fall 2004	72%	15%	12%	1%	**910**
Fall 2005	69%	17%	12%	2%	**1018**
Fall 2006	65%	22%	11%	2%	**1099**
Fall 2007	66%	22%	11%	1%	**1151**

[1] Includes research institutes and other non-profits.

Updated Employment Status of 2006–2007 Doctoral Recipients

The updated response rates for the 2007 Survey of New Doctoral Recipients appear on page 814.

The total number of departments responding in time for inclusion in this Second Report was 252, 37 more than were included in the 2007 First Report but 17 less than the total number responding for inclusion in the 2006 Second Report. No adjustments were made in this report for nonresponding departments. Definitions of the various groups surveyed in the Annual Survey can be found on page 825 of this report.

Table 1A shows the fall and final counts of doctoral recipients in the mathematical sciences awarded by U.S. institutions in each year from 1997 through 2007. This year the total number of new doctoral recipients is 1,333, up from the previous year by 22. A detailed review of responding and nonresponding departments indicates that the increase in doctoral recipients from 2006 to 2007

Figure 1: Percentage of New Doctoral Recipients Unemployed[1]

Year	Percentage
1983	2.2
1984	2.1
1985	0.8
1986	2.3
1987	3.0
1988	1.4
1989	3.0
1990	2.2
1991	5.0
1992	6.7
1993	8.9
1994	10.7
1995	10.7
1996	8.1
1997	3.8
1998	4.9
1999	4.7
2000	3.3
2001	3.7
2002	2.9
2003	5.0
2004	4.4
2005	3.9
2006	3.3
2007	2.4

[1] As reported in the respective Annual Survey Second Reports.

Table 3A: New Doctoral Recipients Employed in the U.S.

	Degree-Granting Department Group[1]													
	I (Pu)		I (Pr)		II		III		IV		Va		TOTAL	
	Academic[2]	Business/ Industry & Government	Academic	Business/ Industry & Government	Academic	Business/ Industry & Government	Academic	Business/ Industry & Government	Academic	Business/ Industry & Government	Academic	Business/ Industry & Government	Academic	Business/ Industry & Government
Fall 2003	123	24	90	16	118	13	61	10	119	54	40	14	551	131
Fall 2004	118	18	118	18	144	17	73	11	150	61	52	11	655	137
Fall 2005	152	21	104	17	152	23	97	18	149	79	45	18	699	176
Fall 2006	171	41	109	21	128	32	93	15	155	104	59	30	715	243
Fall 2007	191	50	91	12	181	20	95	27	151	123	47	24	756	256

[1] For definitions of groups see page 825.
[2] Includes research institutes and other non-profits.

would have been even larger but for the increased number of nonresponding departments for 2007. Of the 242 departments that responded in both 2006 and 2007 the number of degrees awarded increased from 1,216 to 1,307, a 7.5% increase.

Table 1B shows trends in the number of new doctoral recipients for the past five years broken down by U.S. citizens and non-U.S. citizens. This year the number of new doctoral recipients who are U.S. citizens is 576, an increase of 24 (4%) over last year. The number of non-U.S. citizen new doctoral recipients dropped by 2 to 757.

Table 1C gives a breakdown of the 1,333 doctoral degrees awarded in the mathematical sciences between July 1, 2006, and June 30, 2007, by type of degree-granting department.

Table 1D shows the number of U.S. citizens, receiving degrees for the years 1997–1998 through 2006–2007. New this year is the addition of columns showing the percentage of U.S. citizen females and the percentage of U.S. citizen underrepresented minorities. This includes any person having origins in the categories American Indian or Alaska Native, Black or African American, Hispanic or Latino, and Native Hawaiian or Other Pacific Islander.

Tables 2A, 2B, and 2C display updates of these same numbered tables in the First Report to include the 176 additional doctoral recipients reported too late for inclusion in the First Report. New doctoral recipients are grouped by field of thesis using the *Mathematical Reviews* 2000 Mathematics Subject Classification list. A complete list of these groups is available on the AMS website at `www.ams.org/employment/Thesis_groupings.pdf`. At the time of this Second Report, the fall 2007 employment status of 1,190 of the 1,333 doctoral recipients was known.

The fall 2007 unemployment rate for new doctoral recipients, based on information gathered by the time of the Second Report, was 2.4%. Figure 1 presents the fall 1983 through fall 2007 trend in the final unemployment rate of new doctoral recipients. New for this year is the addition of the unemployment rate of female new doctoral recipients for the fall 1992 through 2007. The counts on which these rates are determined do not include those new doctoral recipients whose fall employment status was still unknown at the time of the Second Report. This year the number of recipients whose employment status was reported as unknown decreased to 143 from 163 last year.

Of the 1,190 new doctoral recipients whose employment is known, 1,012 were employed in the U.S., 139 were employed outside the U.S., 28 were still seeking employment, and 11 were not seeking employment.

Table 2D presents the trend in the percentage of employed new doctoral recipients by type of employer for the last five years. Academic employment includes those employed by research institutes and other nonprofits. The percentages reported for fall 2007 are essentially unchanged from those reported for fall 2006. Among new doctoral recipients who are employed in the U.S.,

Table 3B: New Doctoral Recipients Employed in U.S. Academic Positions

	Hiring Department Group[1]					
	I–III	IV	Va	M&B	Other	**TOTAL**
Fall 2003	216	39	9	158	129	**551**
Fall 2004	220	66	19	172	178	**655**
Fall 2005	249	53	12	212	173	**699**
Fall 2006	263	73	14	198	167	**715**
Fall 2007	286	44	15	229	182	**756**

[1] For definitions of groups see page 825.

Table 3C: Females as a Percentage of New Doctoral Recipients

	Department Group[1]							
	I (Pu)	I(Pr)	II	III	IV	Va	M&B	**TOTAL**
% Female								
Produced	25%	25%	30%	35%	49%	23%	-	**33%**
Hired	20%	27%	29%	40%	45%	33%	39%	**34%**

[1] For definitions of groups see page 825.

Table 3D: Citizenship of 2006–2007 Male Doctoral Recipients by Fall 2007 Employment Status

TYPE OF EMPLOYER	CITIZENSHIP				TOTAL MALE DOCTORAL RECIPIENTS
	U.S. CITIZENS	NON-U.S. CITIZENS			
		Permanent Visa	Temporary Visa	Unknown Visa	
U.S. Employer	335	46	268	9	**658**
U.S. Academic	266	34	185	7	**492**
Groups[1] I, II, III, and Va	111	8	95	3	**217**
Group IV	13	2	8	1	**24**
Non-Ph.D. Department	134	22	66	3	**225**
Research Institute/Other Nonprofit	8	2	16	0	**26**
U.S. Nonacademic	69	12	83	2	**166**
Non-U.S. Employer	19	1	87	3	**110**
Non-U.S. Academic	18	1	78	3	**100**
Non-U.S. Nonacademic	1	0	9	0	**10**
Not Seeking Employment	4	0	1	0	**5**
Still Seeking Employment	11	2	9	0	**22**
Subtotal	369	49	365	12	**795**
Unknown (U.S.)	27	1	13	1	**42**
Unknown (non-U.S.)[2]	0	0	47	3	**50**
TOTAL	**396**	**50**	**425**	**16**	**887**

[1] For definitions of groups see page 825.
[2] Includes those whose status is reported as "unknown" or "still seeking employment".

Table 3E: Citizenship of 2006–2007 Female Doctoral Recipients by Fall 2007 Employment Status

TYPE OF EMPLOYER	CITIZENSHIP				TOTAL FEMALE DOCTORAL RECIPIENTS
	U.S. CITIZENS	NON-U.S. CITIZENS			
		Permanent Visa	Temporary Visa	Unknown Visa	
U.S. Employer	151	36	160	7	**354**
U.S. Academic	128	24	106	6	**264**
Groups[1] I, II, III, and Va	37	8	37	2	**84**
Group IV	7	2	10	1	**20**
Non-Ph.D. Department	79	14	48	2	**143**
Research Institute/Other Nonprofit	5	0	11	1	**17**
U.S. Nonacademic	23	12	54	1	**90**
Non-U.S. Employer	8	1	19	1	**29**
Non-U.S. Academic	8	1	19	1	**29**
Non-U.S. Nonacademic	0	0	0	0	**0**
Not Seeking Employment	5	1	0	0	**6**
Still Seeking Employment	3	0	3	0	**6**
Subtotal	167	38	182	8	**395**
Unknown (U.S.)	13	5	4	0	**22**
Unknown (non-U.S.)[2]	0	0	28	1	**29**
TOTAL	**180**	**43**	**214**	**9**	**446**

[1] For definitions of groups see page 825.
[2] Includes those whose status is reported as "unknown" or "still seeking employment".

the percentage taking nonacademic employment varied significantly by field of thesis. For those whose field of thesis is in the first three columns in Table 2A, this percentage is the lowest at 7% (down from 10% last year), while the percentage for those with theses in probability or statistics is the highest at 44% (up from 40% last year).

Table 3A shows that the fall 2007 total number of doctoral recipients taking positions in business/industry and government is 256. This number reflects an increase of 5% over last year. Groups I, II, and III combined are unchanged from their total for fall 2006. Group IV alone accounts for the increase.

Table 3B shows that the number of new doctoral recipients taking U.S. academic positions has increased to 756, from 715 in 2006. Doctoral hires

Table 3F: Number of New Doctoral Recipients Employed in the U.S. by Citizenship and Type of Employer

U.S. EMPLOYER	CITIZENSHIP		TOTAL
	U.S.	Non-U.S.	
Academic: Groups I–Va	168	177	**345**
Academic: M&B, Other	226	185	**411**
Nonacademic	92	164	**256**
TOTAL	**486**	**526**	**1012**

into U.S. academic positions are up in all groups except Groups IV (down to 44 from 73 last year) and Group I (Pr) (down to 64 from 75 last year). The biggest percentage increase is in Group I (Pu) (31%). Doctoral hires into non-U.S. academic positions increased by 8% to 129 from 119 last year.

Table 3C gives information about the production of female new doctoral recipients in the doctoral-granting departments and the hiring of females by all department groups. From Table 3C we see that the percentage of females hired ranges from a high of 45% in Group IV, followed by Group III at 40% to a low of 20% in Group I (Pu). The percentage of female new doctoral recipients produced is highest in Group IV (49%).

Updated Information about 2006–2007 Doctoral Recipients by Sex and Citizenship

Tables 3D and 3E show the sex and citizenship of the 1,333 new doctoral recipients and the fact that 1,012 new doctoral recipients found jobs in the U.S. this year. This is 85% of the 1,190 new doctoral recipients whose employment status was known and 88% of the 1,151 known to have jobs in fall 2007. Last year these percentages were 83% and 87%, respectively.

Sex and citizenship are known for all of the 1,333 new doctoral recipients. The final count of new doctoral recipients who are U.S. citizens is 576 (43%) (up from 42% last year). Pages 258–61 of the First Report present further information related to the citizenship of the 2006–2007 new doctoral recipients.

Of the 576 U.S. citizen new doctoral recipients reported for 2006–2007, 180 are female and 396 are male. Females accounted for 31% of the U.S. citizen total (up from 28% last year). The number of female U.S. citizens has increased by 27 from last year's count of 153, and the number of male U.S. citizens decreased by 3 from last year's count of 399.

Table 3F shows that U.S. citizens accounted for 48% of those employed in the U.S. (up from 46% last year). Groups I through Va hired 49% U.S. citizens, while groups M, B, and all other academic departments hired 55% U.S. citizens (last year these percentages were 42% and 54%, respectively). U.S. citizens represented 36% of those hired into nonacademic positions (last year 39%). Among all the 1,012 new 2006–2007 doctoral recipients employed in the U.S., 25% took nonacademic employment (government or business and industry.) This is the same percentage as last year.

Table 4A: Number (and Percentage) of Annual EENDR Respondents Employed in the U.S. by Job Status

	Employed in U.S.					
	Permanent Total	Temporary Total	Temporary			Unknown
			Permanent not available	Postdoctoral		
				Total	Permanent not available	
Fall 2003	253(54%)	216(46%)	87(40%)	164(76%)	53(32%)	--
Fall 2004	220(49%)	229(51%)	81(35%)	176(77%)	49(28%)	--
Fall 2005	291(56%)	232(44%)	92(40%)	172(74%)	55(32%)	--
Fall 2006	289(51%)	274(49%)	98(36%)	209(76%)	57(27%)	--
Fall 2007	259(53%)	227(47%)	88(39%)	172(76%)	57(33%)	--

Table 4B: Percentage of Annual EENDR Respondents Employed in the U.S. by Employment Sector within Job Status

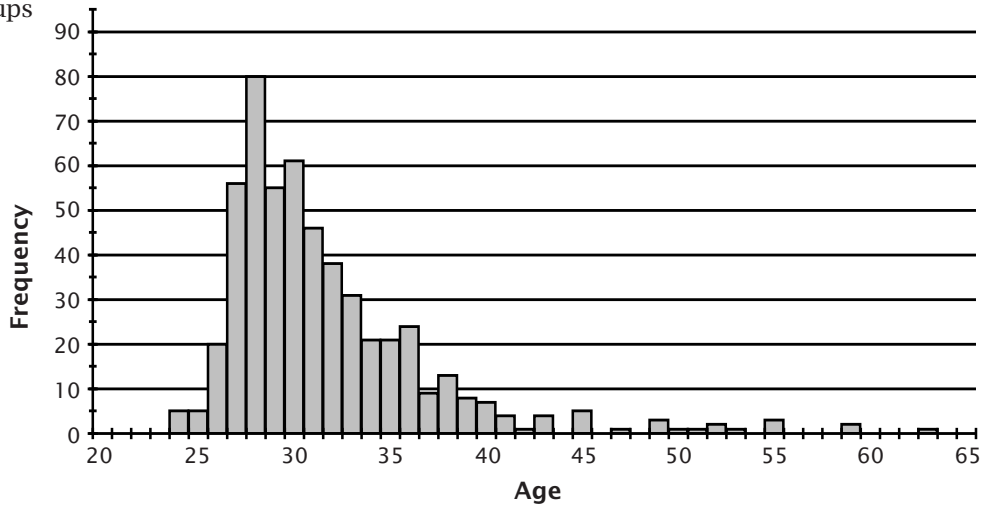
	Employed in U.S.					
	Permanent			Temporary		
	Academic[1]	Government	Business/ Industry	Academic	Government	Business/ Industry
Fall 2003	76%	4%	20%	94%	3%	3%
Fall 2004	72%	5%	23%	97%	3%	--
Fall 2005	68%	5%	27%	96%	4%	--
Fall 2006	66%	4%	30%	93%	5%	2%
Fall 2007	68%	3%	29%	93%	4%	3%

[1] Includes research institutes and other non-profits.

New Information from the EENDR Survey

Of the 1,157 new doctoral recipients reported in the First Report, the 1,028 whose addresses were known were sent the "Employment Experiences of New Doctoral Recipients" (EENDR) survey in October 2007, and 547 (47%) responded. The response rates varied considerably among the various subgroups of new doctoral recipients

Figure 2: Age Distribution of 2006–2007 EENDR Respondents



defined by their employment status as reported by departments. Among those who were employed the highest response rate, 54%, was from those employed in the U.S. academic, while the lowest, 38%, was from those in non-U.S. academic.

The EENDR gathered details on employment experiences not available through departments. The remainder of this section presents additional information available on this subset of the 2006–2007 doctoral recipients.

Table 4A gives the numbers and percentages of EENDR respondents taking permanent and temporary positions in the U.S for fall 2003 through fall 2007.

This year we see that among the 486 employed in the U.S., 259 reported obtaining a permanent position and 227 a temporary position. While these numbers both reflect a decrease, the percentage of individuals taking permanent positions in 2007 has increased to 53% from 51% in 2006, and the percentage of those taking temporary positions has decreased to 47% from 49%. Of the 227 in temporary positions, 88 (39%) reported taking temporary employment because a suitable permanent position was not available. Most respondents classified their temporary position as postdoctoral (76%). Of the 172 respondents taking postdoctal positions, 57 (33%) reported that a suitable permanent position was not available.

Table 4B shows the employment trends of permanent and temporary positions broken down by sector for the last five years. Among the 259 who reported obtaining a permanent position in the U.S. in fall 2007, 68% were employed in academia (including 1% in research institutes and other nonprofits), 3% in government, and 29% in business or industry. Women held 34% of the permanent positions.

Among the 227 individuals with temporary employment in the U.S. this year, 93% were employed in academia (including 8% in research institutes and other nonprofits), 4% in government, and 3% in business or industry.

Figure 2 gives the age distribution of the 529 new doctoral recipients who responded to this question. The median age of new doctoral recipients was 30 years, while the mean age was 32 years. The first and third quartiles were 28 and 33 years, respectively. This distribution is consistent with those of the recent past.

Previous Annual Survey Reports

The 2007 First Report was published in the *Notices* in the February 2008 issue. For the last full year of reports, the 2006 First, Second, and Third Reports were published in the *Notices* in the February, August, and December 2007 issues respectively. These reports and earlier reports, as well as a wealth of other information from these surveys, are available on the AMS website at `www.ams.org/employment/surveyreports.html`.

Starting Salary Survey of the 2006–2007 Doctoral Recipients

The starting salary figures for 2007 were compiled from information gathered on the EENDR questionnaires sent to individuals who received doctoral degrees in the mathematical sciences during the 2006–2007 academic year from universities in the United States (see previous section for more details).

The questionnaires were distributed to 1,157 recipients of degrees using addresses provided by the departments granting the degrees; 547 individuals responded between late October and April. Responses with insufficient data or from individuals who indicated they had part-time or non-U.S. employment were excluded. Numbers of usable responses for each salary category are reported in the following tables.

Readers should be warned that the data in this report are obtained from a self-selected sample, and inferences from them may not be representative of the population.

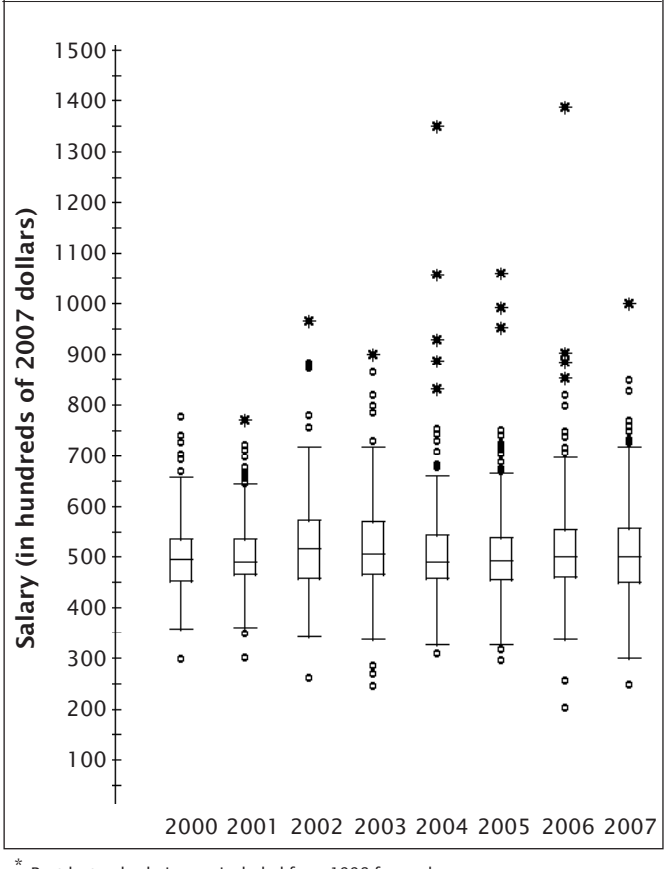
Key to Tables and Graphs. Salaries are those reported for the fall immediately following the survey cycle. Years listed denote the survey cycle in which the doctorate was received—for example, survey cycle July 1, 2006–June 30, 2007, is designated as 2007. Salaries reported as 9–10 months exclude stipends for summer grants or summer teaching or the equivalent. M and F are male and female respectively. Male and female figures are not provided when the number of salaries available for analysis in a particular category was five or fewer. All categories of "Teaching/Teaching and Research" and "Research Only" contain those recipients employed at academic institutions only.

Graphs. The graphs show standard boxplots summarizing salary distribution information for the years 2000 through 2007. Values plotted for 2000 through 2006 are converted to 2007 dollars using the implicit price deflator prepared annually by the Bureau of Economic Analysis, U.S. Department of Commerce. These categories are based on work activities reported in EENDR. Salaries of postdoctorates are shown separately. They are also included in other academic categories with matching work activities.

For each boxplot the box shows the first quartile (Q1), the median (M), and the third quartile (Q3). The interquartile range (IQR) is defined as Q3–Q1. Think of constructing invisible fences 1.5×IQR below Q1 and 1.5×IQR above Q3. Whiskers

Academic Teaching/Teaching and Research 9–10-Month Starting Salaries* (in hundreds of dollars)

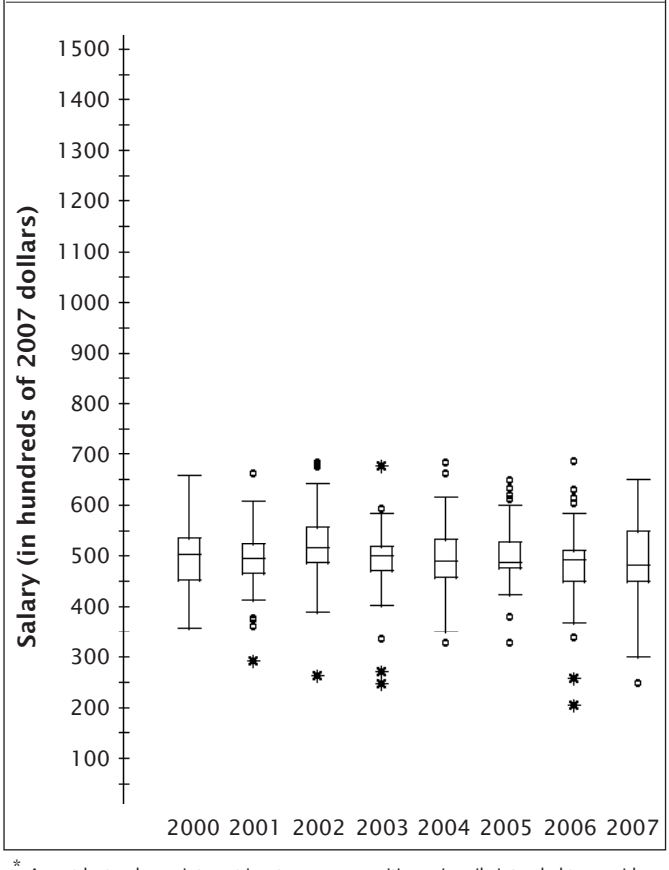
Ph.D. Year	Min	Q_1	Median	Q_3	Max	Reported Median in 2007 $
1980	105	155	171	185	250	379
1985	170	230	250	270	380	429
1990	230	305	320	350	710	469
1995	220	320	350	382	640	455
1998*	140	340	370	410	700	459
2000	250	380	415	450	650	497
2001	259	400	420	461	660	491
2002	230	400	450	500	840	517
2003	220	415	450	510	920	506
2004	285	420	450	500	1234	492
2005	280	430	465	506	1002	492
2006	200	450	490	550	1350	503
2007	250	450	500	560	1000	500
2003 M	220	420	450	509	855	
2003 F	359	414	444	512	920	
2004 M	285	420	450	490	850	
2004 F	300	421	450	500	1234	
2005 M	300	430	465	510	710	
2005 F	280	430	467	501	1002	
2006 M	200	450	499	550	880	
2006 F	270	450	480	520	1350	
Total (180 male/86 female)						
2007 M	320	450	500	558	1000	
2007 F	250	438	490	560	830	
One year or less experience (140 male/69 female)						
2007 M	320	450	500	558	850	
2007 F	250	430	470	545	830	



* Postdoctoral salaries are included from 1998 forward.

Academic Postdoctorates Only* 9–10-Month Starting Salaries (in hundreds of dollars)

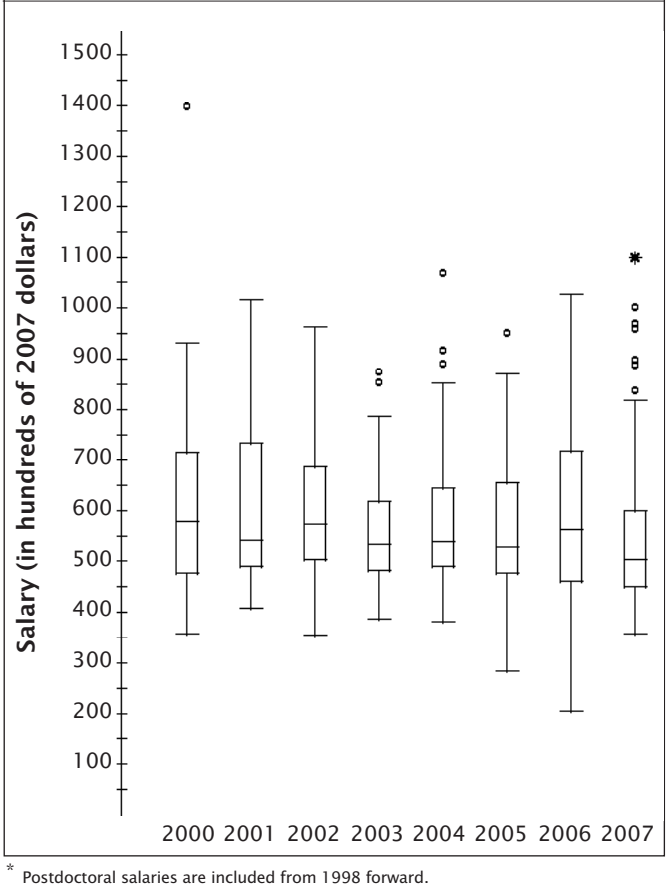
Ph.D. Year	Min	Q_1	Median	Q_3	Max	Reported Median in 2007 $
1997	180	350	385	410	450	483
1998	290	350	390	420	500	484
1999	130	365	400	418	540	489
2000	300	385	420	450	550	503
2001	250	400	425	450	566	497
2002	230	425	450	487	595	517
2003	240	420	450	480	600	506
2004	300	420	450	490	625	492
2005	310	450	460	500	615	487
2006	200	441	480	500	670	493
2007	250	450	483	550	650	483
2003 M	240	420	450	485	600	
2003 F	359	408	449	459	510	
2004 M	300	420	450	480	625	
2004 F	400	440	470	500	606	
2005 M	310	450	470	500	615	
2005 F	400	437	450	471	500	
2006 M	200	450	483	523	670	
2006 F	330	413	464	500	590	
Total (59 male/24 female)						
2007 M	360	450	490	575	650	
2007 F	250	425	470	515	650	
One year or less experience (47 male/23 female)						
2007 M	360	450	500	580	650	
2007 F	250	423	465	523	650	



* A postdoctoral appointment is a temporary position primarily intended to provide an opportunity to extend graduate training or to further research experience.

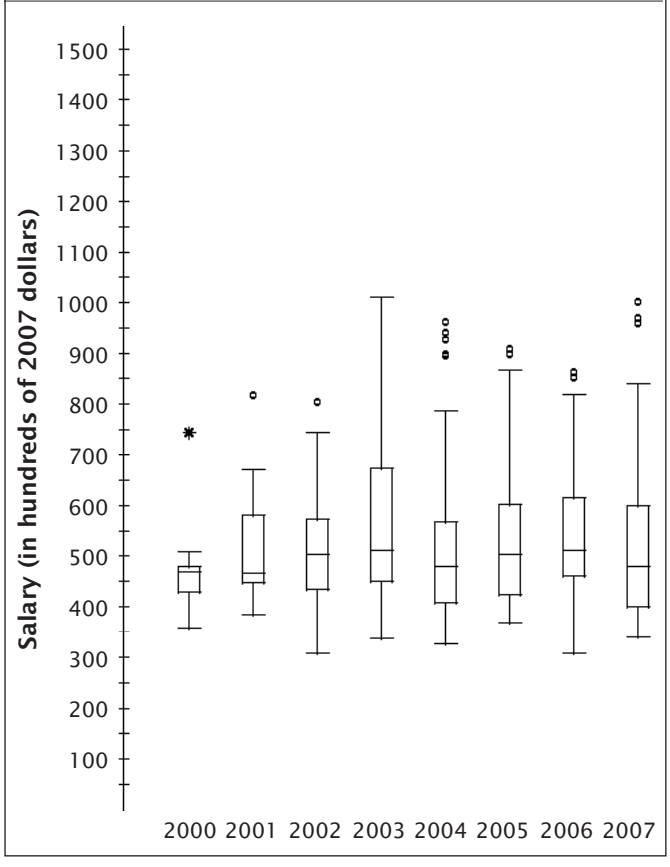
Academic Teaching/Teaching and Research 11–12-Month Starting Salaries* (in hundreds of dollars)

Ph.D. Year	Min	Q_1	Median	Q_3	Max	Reported Median in 2007 $
1985	220	230	273	300	470	469
1990	225	318	365	404	670	535
1995	300	354	410	478	600	533
1998*	275	405	480	575	700	595
2000	300	400	485	600	1170	580
2001	350	420	465	615	870	543
2002	310	439	500	597	840	574
2003	345	438	475	550	780	534
2004	350	450	495	583	980	541
2005	270	450	500	615	900	530
2006	200	450	550	700	1000	565
2007	340	450	504	600	1100	504
2003 M	397	440	490	555	780	
2003 F	345	400	440	513	620	
2004 M	350	448	487	533	980	
2004 F	380	465	545	605	650	
2005 M	270	455	490	549	900	
2005 F	420	450	570	753	824	
2006 M	300	450	535	685	900	
2006 F	200	520	600	850	1000	
Total (56 male/26 female)						
2007 M	360	440	500	600	1100	
2007 F	340	480	529	703	1003	
One year or less experience (44 male/22 female)						
2007 M	360	424	500	600	970	
2007 F	340	458	500	690	1003	



Academic Research Only 11–12-Month Starting Salaries (in hundreds of dollars)

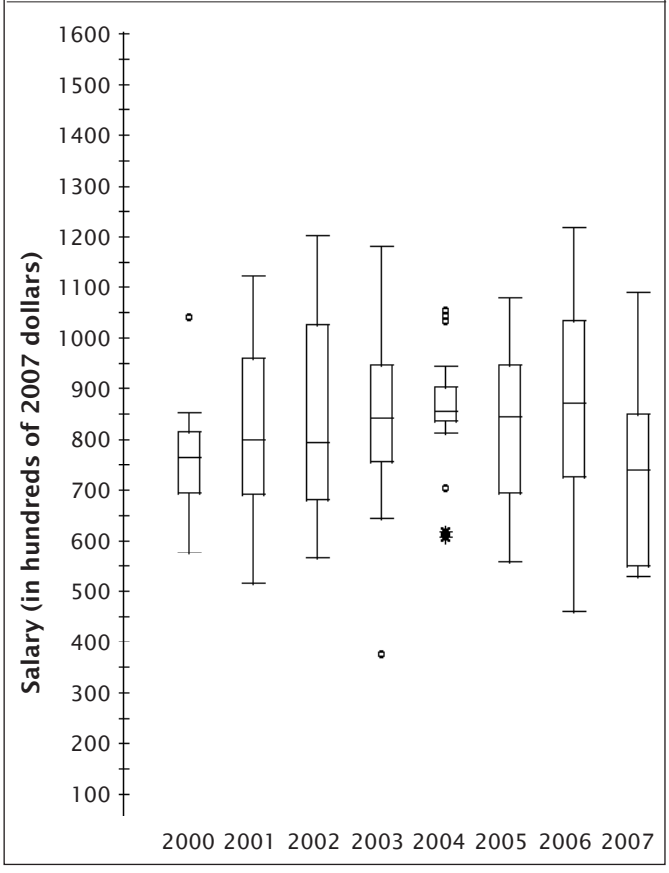
Ph.D. Year	Min	Q_1	Median	Q_3	Max	Reported Median in 2007 $
1997	190	300	350	400	600	439
1998	200	333	360	428	617	447
1999	270	380	400	480	720	489
2000	300	365	400	529	1000	479
2001	300	350	400	575	796	468
2002	270	380	440	500	700	505
2003	300	405	455	600	900	512
2004	300	378	440	510	880	481
2005	350	400	475	570	860	503
2006	300	450	500	600	840	513
2007	340	415	480	540	1003	480
2003 M	300	410	440	505	820	
2003 F	310	390	480	650	900	
2004 M	300	380	440	560	880	
2004 F	350	378	430	493	820	
2005 M	350	420	480	580	860	
2005 F	350	400	475	529	850	
2006 M	350	450	500	600	830	
2006 F	300	455	540	680	840	
Total (25 male/11 female)						
2007 M	360	400	470	600	970	
2007 F	340	465	480	504	1003	
One year or less experience (21 male/11 female)						
2007 M	360	400	440	600	970	
2007 F	340	465	480	504	1003	



* Postdoctoral salaries are included from 1998 forward.

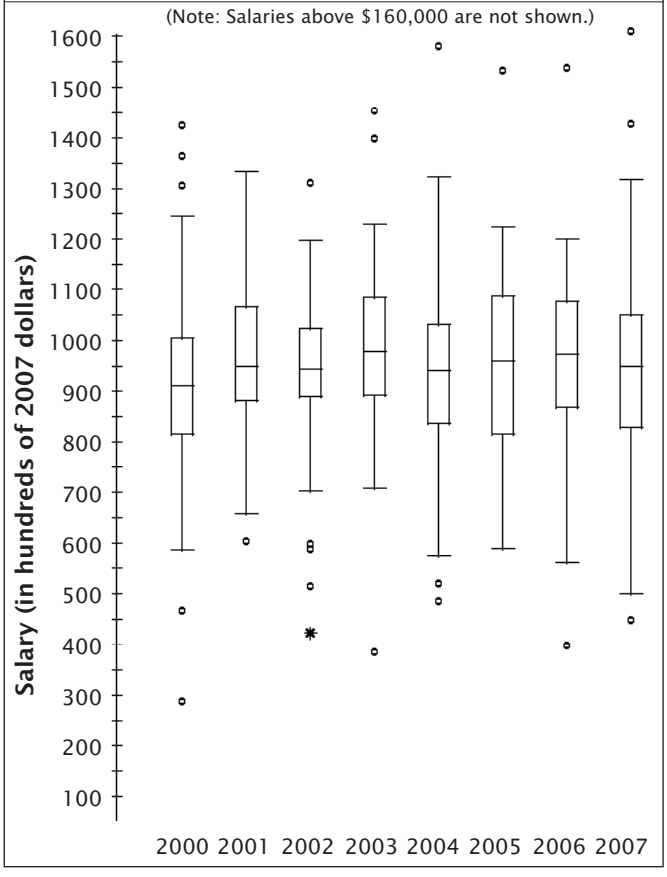
Government
11–12-Month Starting Salaries
(in hundreds of dollars)

Ph.D. Year	Min	Q_1	Median	Q_3	Max	Reported Median in 2007 $
1985	263	294	325	381	440	558
1990	320	345	378	430	587	554
1995	370	440	494	507	650	642
1999	400	495	550	651	720	673
2000	440	540	600	640	830	718
2001	400	580	644	758	920	753
2002	450	551	650	775	1005	747
2003	290	668	705	763	1008	793
2004	510	720	738	780	920	807
2005	480	610	752	848	972	796
2006	400	678	800	961	1140	821
2007	480	500	690	800	1040	690
2003 M	290	648	710	788	830	
2003 F	600	683	695	723	1008	
2004 M	520	700	730	740	910	
2004 F	510	733	749	790	920	
2005 M	500	668	790	902	955	
2005 F	480	540	750	770	972	
2006 M	500	660	800	960	1000	
2006 F	400	775	790	1043	1140	
Total (12 male/1 female)						
2007 M	480	500	695	813	1040	
2007 F	To few women to report separately.					
One year or less experience (10 male/1 female)						
2007 M	480	500	655	747	990	
2007 F	To few women to report separately.					



Business and Industry
11–12-Month Starting Salaries
(in hundreds of dollars)

Ph.D. Year	Min	Q_1	Median	Q_3	Max	Reported Median in 2007 $
1985	260	360	400	420	493	687
1990	320	438	495	533	700	726
1995	288	480	568	690	1250	738
1999	360	600	680	761	2450	832
2000	200	640	720	800	1500	862
2001	475	716	770	865	1850	900
2002	325	734	780	850	1400	896
2003	300	700	800	900	1250	900
2004	400	728	817	900	1800	893
2005	510	755	870	978	2000	921
2006	340	800	900	1000	1550	924
2007	400	780	900	1000	2500	900
2003 M	550	725	840	920	1250	
2003 F	300	628	780	816	900	
2004 M	400	710	813	900	1800	
2004 F	480	789	850	900	1100	
2005 M	510	760	930	1005	2000	
2005 F	600	745	860	890	1100	
2006 M	340	750	890	1000	1450	
2006 F	500	850	900	960	1550	
Total (45 male/24 female)						
2007 M	400	760	920	1000	2500	
2007 F	710	800	855	950	1270	
One year or less experience (35 male/17 female)						
2007 M	400	780	855	975	2500	
2007 F	710	715	720	725	730	



Definitions of the Groups

As has been the case for a number of years, much of the data in these reports is presented for departments divided into groups according to several characteristics, the principal one being the highest degree offered in the mathematical sciences. Doctoral-granting departments of mathematics are further subdivided according to their ranking of "scholarly quality of program faculty" as reported in the 1995 publication *Research-Doctorate Programs in the United States: Continuity and Change*.[1] These rankings update those reported in a previous study published in 1982.[2] Consequently, the departments which now comprise Groups I, II, and III differ significantly from those used prior to the 1996 survey.

The subdivision of the Group I institutions into Group I Public and Group I Private was new for the 1996 survey. With the increase in number of the Group I departments from 39 to 48, the Data Committee judged that a further subdivision of public and private would provide more meaningful reporting of the data for these departments.

Brief descriptions of the groupings are as follows:

Group I is composed of 48 doctoral-granting departments with scores in the 3.00–5.00 range. Group I Public and Group I Private are Group I doctoral-granting departments at public institutions and private institutions respectively.

Group II is composed of 56 doctoral-granting departments with scores in the 2.00–2.99 range.

Group III contains the remaining U.S. doctoral-granting departments, including a number of departments not included in the 1995 ranking of program faculty.

Group IV contains U.S. doctoral-granting departments (or programs) of statistics, biostatistics, and biometrics reporting a doctoral program.

Group V contains U.S. doctoral-granting departments (or programs) of applied mathematics/applied science, operations research, and management science.

Group Va is applied mathematics/applied science doctoral-granting departments; Group Vb, which is no longer surveyed as of 1998–99, was operations research and management science.

Group M or Masters contains U.S. departments granting a master's degree as the highest graduate degree.

Group B or Bachelors contains U.S. departments granting a baccalaureate degree only.

Listings of the actual departments which comprise these groups are available on the AMS website at `www.ams.org/outreach`.

[1] Research-Doctorate Programs in the United States: Continuity and Change, *edited by Marvin L. Goldberger, Brendan A. Maher, and Pamela Ebert Flattau, National Academy Press, Washington, DC, 1995.*

[2] *These findings were published in* An Assessment of Research-Doctorate Programs in the United States: Mathematical and Physical Sciences, *edited by Lyle V. Jones, Gardner Lindzey, and Porter E. Coggeshall, National Academy Press, Washington, DC, 1982. The information on mathematics, statistics, and computer science was presented in digest form in the April 1983 issue of the* Notices, *pages 257–67, and an analysis of the classifications was given in the June 1983* Notices, *pages 392–3.*

are drawn from Q3 to the largest observation that falls below the upper invisible fence and from Q1 to the smallest observation that falls above the lower invisible fence. Think of constructing two more invisible fences, each falling 1.5×IQR above or below the existing invisible fences. Any observation that falls between the fences on each end of the boxplots is called an outlier and is plotted as ∘ in the boxplots. Any observation that falls outside of both fences either above or below the box in the boxplot is called an extreme outlier and is marked as × in the boxplot.

Acknowledgments

The Annual Survey attempts to provide an accurate appraisal and analysis of various aspects of the academic mathematical sciences scene for the use and benefit of the community and for filling the information needs of the professional organizations. Every year, college and university departments in the United States are invited to respond. The Annual Survey relies heavily on the conscientious efforts of the dedicated staff members of these departments for the quality of its information. On behalf of the Data Committee and the Annual Survey Staff, we thank the many secretarial and administrative staff members in the mathematical sciences departments for their cooperation and assistance in responding to the survey questionnaires.

Other Data Sources

American Association of University Professors, Financial *Inequality in Higher Education: The Annual Report on the Economic Status of the Profession 2006–2007*, Academe: Bull. AAUP (March/April 2007), Washington, DC.

American Statistical Association, *2007–2008 Salary Report of Academic Statisticians*. (Published in *AMSTATNEWS*, December 2007, Issue #366.)

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Commission on Professionals in Science and Technology, *Professional Women and Minorities: A Total Human Resources Data Compendium*, 16th ed., CPST, (November 2006), Washington, DC.

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———, *Strengthening the Linkages between the Sciences and the Mathematical Sciences*, National Academy Press, Washington, DC, 2000.

———, *U.S. Research Institutes in the Mathematical Sciences: Assessment and Perspectives*, National Academy Press, Washington, DC, 1999.

———, *Research-Doctorate Programs in the United States: Continuity and Change*, National Academy Press, Washington, DC, 1995.

National Science Board, *Science and Engineering Indicators—2008*. Two Volumes (NSB 08-01; NSB 08-1A), National Science Foundation, Arlington, VA, 2008.

National Science Foundation, *U.S. Doctorates in the 20th Century*, (NSF 06-319), Arlington, VA, 2006.

———, *Graduate Students and Postdoctorates in Science and Engineering: Fall 2005* (NSF 07-321), Arlington, VA, 2007.

———, *Science and Engineering Degrees: 1966–2004* (NSF 07-307), Detailed Statistical Tables, Arlington, VA, 2007.

———, *Science and Engineering Degrees, by Race/Ethnicity of Recipients: 1995–2004* (NSF 07-388), Detailed Statistical Tables, Arlington, VA, 2007.

———, *Science and Engineering Doctorate Awards: 2005* (NSF 07-305), Detailed Statistical Tables, Arlington, VA, 2006.

———, *Women, Minorities, and Persons with Disabilities in Science and Engineering Data Update* (March 2006). (`http://www.nsf.gov/statistics/wmpd/pdf/march2006updates.pdf`)

Doctoral Degrees Conferred 2006–2007

Supplementary List

The following list supplements the list of thesis titles published in the February 2008 *Notices*, pages 280–99.

CALIFORNIA

California Institute of Techology (4)

CONTROL AND DYNAMICAL SYSTEMS

Chen, Lijun, Wireless network design and control.

Lui, Xin, Robustness, complexity, validation and risk.

Mysore, Shreesh, Structural plasticity in neuronal networks.

Martinez, Alfredo, A treatise on econometric forecasting.

Naval Postgraduate School (1)

MATHEMATICS

Johnson, Anthony, A time dependent finite element approach to optimizing seismic sonar arrays.

University of California, Berkeley

(14)

STATISTICS

Bourgon, Richard, Chromatin-immune precipitation and high density tiling microarrays: A generative model, methods for analysis and methodology assessment in the absence of a "gold standard".

Cho, Young, Estimating velocity fields on a freeway from low resolution video.

Lasiecki, Pawel, Assessment of stochastic differential equation and Markov chain models in time series.

Li, Bo, On goodness-of-fit tests of semiparametric models.

Panaretos, Victor, Inverse problems, stochastic geometry, structural biology.

Roch, Sebastien, Markov models on trees: Reconstruction and applications.

Yi, Jing, Absolute and relative quantification of fluorescently labelled DNA.

GROUP IN BIOSTATISTICS

Bein, Edward, Topics in causal inference: Analyzing psychotherapy outcome studies, convex-combination estimators, and *G*-computations model selection.

Petersen, Maya, Applications of causal inference methods to improve the treatment of antiretroviral-resistant HIV infection.

Tang, Hui, Finding DNA cis-regulatory elements using regression methods.

Teng, Siew-Leng, Statistical methods in integrative analysis of gene expression data with applications to biological pathways.

Young, Jessica, Statistical methods for complicated current status and high-dimensional data structures with applications in environmental epidemiology.

Zhou, Yun, Statistical issues in a case-control study of gene expression in postmortem human brains.

Wang, Yue, Data-adaptive estimation in causal inference for point treatment study.

University of California, Los Angeles

(9)

BIOSTATISTICS

Alber, Susan, A partition model for treatment effects and treatment-covariate interactions.

Chiang, Lu-May, A Bayesian adaptive design for 2-drug combination phase I clinical trials with ordinal toxicity outcomes.

Gadallah, May, Combining aggregated and individual level data to estimate individual level parameters: Variance, covariance, and slope coefficient.

Kim, Hyun Jung, Classification in Thoracic computated tomagraphy image data.

Lemus, Hector, Bayesian state space modeling of heterogeneous multivariate longitudinal data.

Park, Grace Song-Ye, Modeling longitudinal radiographic progression patterns in rheumatoid arthritis.

Wu, Tongtong, A partial linear semiparametric additive risk model for two-stage design survival studies.

Zhao, Yu, Additive risks regression for survival data from two-stage designs.

Zhou, Kefei, A unified approach to nonparametric comparisons of receiver operating characteristic curves for longitudinal and clustered data.

Stanford University (9)

STATISTICS

Guo, Yaqian, High dimensional classification with application in microarray analysis.

Jin, Wei, A Bayesian approach for additive-multiplicative hazard models.

Kapp, Amy, Cluster analysis with the in-group proportion.

Mathis, Charles, A statistic for measuring the value of side information in investment.

Park, Mee Young, Generalized linear models with regularization.

Purdom, Elizabeth, Multivariate kernel methods in the analysis of graphical structures.

Shi, Jianxin, Quantitative trait mapping using large pedigrees and model selection.

Stodden, Victoria, Model selection when the number of variables exceeds the number of observations.

Tribble, Seth, Markov chain Monte Carlo algorithms using complexly uniformly distributed sequences.

CONNECTICUT

Wesleyan University (2)

MATHEMATICS AND COMPUTER SCIENCE

Gochev, Vasil, Compact-open-like topologies on C(K) and applications.

Lu, Yun, Reducts of countably categorical graphs.

FLORIDA

University of Florida (16)

MATHEMATICS

Gray, Peter, The predictable projection and the predictable dual projection of a two parameter stochastic process.

Guo, Weihong, Medical Image segmentation and diffusion weighted magnetic resonance image analysis.

Keeran, Willard, Coexistence in a feedback-mediated chemostat.

Liu, Juan, Information theoretic content and probability.

Nenciu, Andriana, Characters of finite groups.

Smith, Justin, Discrete groups from a course perspective.

Turygin, Yuri, Borsuk-Ulam property of finite group actions on manifolds and applications.

Zahnen, Jeffrey, Penalized maximum likelihood methods for emission tomography.

Zhang, Hongchao, Gradient methods for large-scale nonlinear optimization.

STATISTICS

Kim, Bong-Rae, Statistical models for clustering dynamic gene expression profiles.

Liu, Xuefeng, Bayesian methodology for models with multivariate (longitudinal) outcomes.

Mergel, Victor, Divergence loss for shrinkage estimation, prediction and prior selection.

Mukhopadhyay, Siuli, Multiresponse, GLM, and other recent approaches in response surface methodology.

Yang, Jie, Nonparametric functional mapping for quantitative trait loci.

Zhang, Li, Bayesian methods in case-control studies with application in genetic epidemiology.

Zhu, Yun, Application of asymmetric Laplace Law in financial risk measures and time series analysis.

ILLINOIS

University of Illinois at Chicago (1)

DIVISION OF EPIDEMIOLOGY AND BIOSTATISTICS

Chosy, Erin, Correlates and health consequences of victimization in a sample of chemically-dependent detainees.

IOWA

University of Iowa (2)

APPLIED MATHEMATICS AND COMPUTATIONAL SCIENCE

Coskun, Huseyin, Mathematical models for amoeboid cell mutility and model based inverse problems.

Shimanovich, Victoria, Optimization of large scale sparse nonlinear systems for flexible protein conformation.

KANSAS

Kansas State University (3)

MATHEMATICS

Koshkin, Sergiy, Homogeneous spaces & Faddeev-Skyrme.

Pasko, Brian, The cohomology of a matrix subgroup.

Randriampiry, Njinasoa, On A-quasiconvex functions and weak lower semicontinuity.

MARYLAND

John Hopkins University (5)

APPLIED MATHEMATICS AND STATISTICS

Aksakalli, Vural, Protocols for stochastic shortest path problems with dynamic learning.

Feng, Jian, Some probability and statistics problems in protemics research.

Hu, Jiang, Sequential designing and terminal analysis of multinomial data.

Nickel, Christine, Random dot product graphs: A model for social networks.

Tucker, Kimberly, Exact and asymptotic dot product representations of graphs.

MASSACHUSETTS

Brandeis University (7)

MATHEMATICS

Balasubramanyam, Baskar, Hida families of Hilbert modulor forms and *p*-adic *L*-functions.

Dousmanis, Gerasimos, Families of Wach modules and two-dimensional crystalline Galois representations.

Gospodinov, Georgi, Relative invariants of Legendrian knots.

Lai, Hsin-Hong, The invariance of virtual classes under blow up of a point when g=0.

Li, Ji, Counting prime graphs and point-determining graphs using combinatorical theory of species.

Rajagopalan, Sridhar, Heegaard Floer homology and symmetrices of knots and links

Song, Balin, On the equivariant cohomology of the genus zero moduli space for stable maps to a grassmanian.

Harvard University (6)

MATHEMATICS

Chen, Jy-Ying Janet, The degree 4 *L*-function of an automorphic form full level on the rank 2 real symplectic group.

Cotterill, Ethan, Enumerative geometry of curves with exceptional secant planes.

Jain, Sonal, Minimal heights and regulators for elliptic surfaces.

Lobb, Andrew, A slice genus lower bound from sl(n) Khovanov-Rozansky homology.

Mok, Chung-Pang, The exceptional zero conjecture for Hilbert modular forms.

Shin, Sug Woo, Counting points on lgusa varieties.

MISSISSIPPI

University of Mississippi (7)

MATHEMATICS

Bokka, Sankar, Statistical tests for the identification of differentially expressed genes.

Dolo, Samuel, A nonparametric test for scale in univariant population setup.

Garner, Latonya, A partially exchangeable model with applications to correlated binary data.

Horton, Leslie, Enumerations of independent sets in graph.

Keeton, Stephanie, The semiparametric exchangeable mode and its applications.

Nicholson, Emlee, Long cycles and paths containing *K*-ordered vertices in graphs.

Smith, Pamela, An efficient nonparametric test for bivariant two-sample location problem.

MISSOURI

Missouri University of Science & Technology (1)

MATHEMATICS AND STATISTICS

Hu, Xiaojun, Distributional aspects of *P*-values and their use in multiple testing situations.

Washington University (9)

MATHEMATICS

Amei, Amei, A time-dependent Poisson random field model of polymorphism within and between two related species.

Brown, Ben, Ehrhart theory of lattice polytopes.

Knese, Greg, Schwartz lemmas on the polydisk.

Koester, Paul, Estimates on a generalization of the Erdos Tiran function.

Kuttykrishnan, Sooraj, Stably tame polynomial automorphisms of polynormal rings in two variables over a UFD.

Lim, Wang Q., Wavelets with composite dilations and their applications.

Randle, Kim, Combinatorial properties of the conjugacy class subgroup partially ordered set of finite groups.

Vegulla, Prasda, Geometry of distinguished varieties.

Wiechmann, Aaron, Recognition of thin position and the additivity conjectures.

MINNESOTA

University of Minnesota (22)

SCHOOL OF MATHEMATICS

Collins, Kevin, An inverse problem in determining the electrical potential on the heart.

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Huska, Juraj, Qualitative properties of second order parabolic equations.

Jia, Ning, Matroids, Schubert polynomials and Fibonacci trees.

Karunathilake, Upali, A representation theorem for certain solutions to Burger's equation.

Kim, Pilwon, Invariantization of numerical schemes for differential equations using moving frames.

Kim, Yang-Jin, Mathematical modeling of cell movement and tumor spheroid growth in vitro.

Koch, Gabriel, A Liouville theorem for the two-dimensional Navier-Stokes equations.

Lee, Chang-Hyeong, Stochastic analysis of biochemical reaction networks.

Luo, Jun, On the rate of convergence of the finite-difference approximations for parabolic Bellman equations with constant coefficients.

Nien, Chu-Feng, Models of representations of general linear groups over *p*-adic fields.

Park, Jinhae, Mathematical modeling and analysis of ferroelectricity in liquid crystals.

Swenson, James, The mod-2 cohomology of finite coxeter groups.

Tarfulea, Nicoleta, Mathematical modeling of signal transduction and cell mobility in tumor angiogensis.

Taskin, Muge, Properties of four partial orders on standard young tableaux.

Wang, Haiyang, Hybridization of the continuous Galerkin finite element method for second-order elliptic and linear elasticity problems.

Wittman, Todd, Variational approaches to digital image zooming.

Xu, Fei, Homological properties of category algebras.

Zhang, Tianyu, Numerical simulation of Ferromagnetic shape memory thin film.

Drake, Daniel, Towards a combinatorial theory of multiple orthogonal polynomials.

Gantner, Ryan, Branching annihilating random walks and their application to traffic flow.

Harrelson, Eric, The homology of the open-closed Riemann surface dioperad and open-closed string topology.

NEW HAMPSHIRE

Dartmouth College (8)

MATHEMATICS

Campos, Oscar, Asymptotic tensor norms.

Dorais, Francois, Souslin trees and degrees of constructibility.

Esselstein, Rachel, On the complexity of building a graph with given neighborhoods.

Klyve, Dominic, Explicit bounds on twin primes and Brun's constant.

Moseman, Elizabeth, The combinatorics of coordinate percolation.

Setyadi, Alison, The affine buildings of SLn and Spn: A combinatorial perspective.

Storm, Christopher, Extending the Ihara-Selberg zeta function of hypergraphs.

Tou, Erik, Zeta Functions for a class of cocompact arithmetic lattices in SL(3,R).

NEW JERSEY

Stevens Institute of Technology (2)

MATHEMATICAL SCIENCES

Babaali, Parisa, Genesic and structural properties of random automata.

Strigul, Nikolai, A new method of scaling vegetation dynamics from individual level to forest ecosystems based on crown plasticity.

Rutgers University - Newark (1)

MATHEMATICS AND COMPUTER SCIENCE

Malik, Vidur, Curves generated on surfaces by the Gilman-Maskit algorithm.

Rutgers University - New Brunswick (4)

STATISTICS AND BIOSTATISTICS

Chang, Denise, Individualized hospital report cards.

Fang, Jiangang, Network tomography: the estimation of traffic matrix and link delay.

Tang, Weihua, Conditional false discovery rate and significance analysis of microarray data.

Yue, Shentu, Some advances in causal inference with missing data and dichotomization of response in regression analysis.

NEW York

New York University, Courant Institute (11)

MATHEMATICS

Ariel, Gil, Effective stochastic dynamics in deterministic systems: Model problems and applications.

Barrerio, Andrea, Wave driven vertex of dynamics in the surf zone.

Calle, Maria, Mean curvature flow and minimal surfaces.

Hayes, Edward, The application of a semi-analytical method for computing asymptotic approximations to option prices.

Konig, Christoff, Arctic landfast sea ice.

Korotianev, Mikhail, Torelli-type theorem for curves defined over finite fields.

Ly, Cheng, Population density approach to neural network modeling: Dimension reduction analysis, technique, and firing rate dynamics.

Mori, Yoichiro, A three-dimensional model of cellular electrical activity.

Rutenburg, Alexander, PoRST Hamiltonian ten bulk-quantified gange theory.

Wright, Paul, Rigorous results for the periodic oscillation of adiabatic piston.

Zhu, Guo Dong (Ernest), Pricing options on trading strategies.

State University of New York at Buffalo (1)

BIOSTATISTICS

Majumdar, Antara, Maximum liklihood estimation of models based on the Monte Carlo EM.

OHIO

Case Western Reserve University (18)

EPIDEMIOLOGY AND BIOSTATISTICS

Bochud, Murielle, Family-based association studies of the genetic determinants of renal sodium handling.

Hu, Simin, New methods for variable selection with applications to survival analysis and statistical redundancy using gene expression data.

Katamba, Achilles, Efficiency of sputum microscopy in diagnosis and cost-effectiveness of 6-month and 8-month treatment of new smear positive pulmonary setting of high HIV prevalence.

Larkin, Emma, A genetic analysis of correlated traits: The apena hypopnea index and body mass index.

Miller, Katherine, Genetic susceptibility in Alzheimer's disease and the role of lipid metabolism.

Nakku-Joloba, Edith, The seroprevalence and incidence of Herpes 1 and 2 in Kampala, Uganda.

Peterson, Lars, Contextual associations of unmet health care locations.

Sinha, Moumita, Estimation of haplotype frequencies from data.

Sinha, Ritwik, Efficient confidence sets for disease gene.

Stubblefield, Angelique, Healthcare utilization and risk for intentional injury death among Ohio children enrolled in Medicaid, 1992-1998.

Sucheston, Lara, Statistical methods for the genetic analysis of developmental disorders.

Terris, Darcey, Maximizing efficiency in risk adjustment under conditions of uncertainty and resources constraints.

Thompson, Cheryl, Stratified linkage analysis based on population substructure.

Trapl, Erika, Understanding adolescent survey responses: impact of mode and other characteristics on data outcomes and quality.

Xing, Chao, Topics in multipoint linkage and association analysis.

Xing, Guan, A simple new method for robust estimation.

Xu, Zhiying (Cindy), A quantitative trait linkage method for longitudinal pedigree data and its application.

Zhou, Esther, Treatment outcomes for socialized prostate patients: From individual to population.

Ohio State University, Columbus (1)

MATHEMATICS

Stey, George Carl, Asymptotic expansion for the L' Norm of N-fold convolutions.

PENNSYLVANNIA

University of Pittsburgh (9)

BIOSTATISTICS

Chen, Huanyu, Experimental design for unbalanced data involving a two level logistic model.

Dai, Feng, Variance components models in statistical genetics: Extensions and applications.

Dean, Leighton, A method for detecting optimal splits over time in survival analysis using tree-structured models.

Ko, Feng-shou, Identification and assessment of longitudinal biomarkers using frailty models in survival analysis.

Li, Jia, A strategy for stepwise regression procedures in survival analysis with missing covariates.

Lin, Yan, Statistical issues in family-based genetic association studies with application to congenital heart defects in Down syndrome.

Soaita, Adina, GEE models for the longitudinal analysis of the effects of occupational radiation exposure on lymphocyte counts in Russian nuclear workers.

Xu, Qing, Inference on survival data under nonproportional hazards.

Yu, Shui, A tree-structured survival model with incomplete and time-dependent covariates: Illustrations using type 1 diabetes data.

RHODE ISLAND

Brown University (3)

BIOSTATISTICS

Lee, Joo Yeon, Sensitivity analysis and informative priors for longitudinal binary data with dropout.

Shiu, Shang-Ying, PROC and ROC analysis: Effective of threshold value for diagnostic test and reference standard.

Su, Li, Bayesian semiparametric regression for censored and incomplete longitudinal data.

SOUTH CAROLINA

Clemson University (4)

MATHEMATICAL SCIENCES

Engau, Alexander, Beyond pareto optimality: Domination and decomposition in multiobjective programming.

Eyabi, Gilbert, Some properties of L(2,1)-coloring as related to the channel assignment problem.

Lockard, Shannon, Random vectors over finite fields.

Singh, Vijay, Equitable efficiency in multiple criteria optimization.

TEXAS

Southern Methodist University (3)

STATISTICAL SCIENCE

Chen, Zhongxue, Probe-level data analysis for high-density oligonucleotide arrays.

Gu, Kangxia, The comparison of two poisson rates.

Lin, Qihua, Bayesian hierarchical spatiotemporal modeling of functional magnetic resonance imaging data.

Texas Tech University (3)

MATHEMATICS AND STATISTICS

McGee, Shelly, Computational modeling of chemical transport in flow structure interaction in porus media.

McGee, Wayne, h-p-k least squares finite element methodology and implementation for fluid-structure interaction.

Yan, Ke, Variance reduction for kernel estimators in clustered longitudinal data analysis.

VIRGINIA

Virginia Commonwealth University (2)

BIOSTATISTICS

Davenport, James, An adaptive dose-finding design using a non-responde model.

Zhao, Jianmin, Optimal clustering: genetic constrained K- and linear programming algorithms.

WISCONSIN

University of Wisconsin - Milwaukee (2)

MATHEMATICAL SCIENCES

Geliazkova, Maya, Spatial thresholding procedures in fMRI data.

Van Groningen, Anthony, Graded multiplicities of the nullcone for the algebraic symmetric pair of type G.

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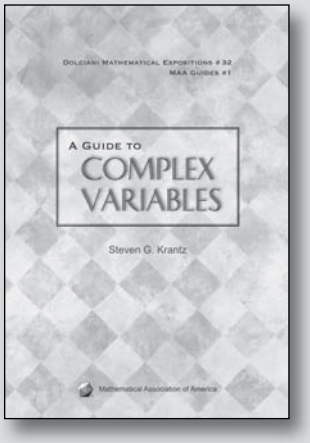
Mathematical Association of America

A Guide to Complex Variables *is the first in a series of MAA Guides written by experts who will provide an overview of a large variety of mathematical topics. Each guide will include key definitions, theorems, and references. They will be useful to students, especially graduate students preparing for qualifying exams and for faculty who have been away from the subject for a number of years. Other volumes in preparation include guides to algebra, number theory and real analysis.*



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A Guide to Complex Variables

SERIES: Dolciani | Volume 1, The MAA Guides

Steven G. Krantz

This is a book about complex variables that gives the reader a quick and accessible introduction to the key topics. While the coverage is not comprehensive, it gives the reader a solid grounding in this fundamental area. There are figures and examples to illustrate the principal ideas, and the exposition is lively and inviting.

Most every mathematics Ph.D. student must take a qualifying exam in complex variables. The task is a bit daunting, because the literature is vast and diverse. It is difficult for students to focus on the essential parts of the subject. What must one absolutely know for the qualifying exam? What will be asked? What techniques will be stressed? What are the key facts? The purpose of this Guide is to answer these questions.

Undergraduate students who want to have a first look at this subject will find that this book provides a good place to start. Professional mathematicians will find it a useful resource as well.

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1. The Complex Plane: Complex Arithmetic; The Exponential and Applications; Holomorphic Functions; Holomorphic and Harmonic Functions. **2.** Complex Line Integrals: Real and Complex Line Integrals; Complex Differentiability and Conformality; The Cauchy Integral Formula and Theorem; The Limitations of the Cauchy Formula. **3.** Applications of the Cauchy Theory: The Derivatives of a Holomorphic Function; The Zeros of a Holomorphic Function. **4.** Laurent Series: Behavior Near an Isolated Singularity; Expansion around Singular Points; Examples of Laurent Expansions; The Calculus of Residues; Applications to Integrals; Singularities at Infinity. **5.** The Argument Principle: Counting Zeros and Poles; The Local Geometry of Holomorphic Functions; Further Results; The Maximum Principle; The Schwarz Lemma. **6.** The Geometric Theory: The Idea of a Conformal Mapping; Linear Fractional Transformations; The Riemann Mapping Theorem; Conformal Mappings of Annuli. **7.** Harmonic Functions: Basic Properties of Harmonic Functions; The Maximum Principle and the Mean Value Property; The Poisson Integral Formula; Regularity of Harmonic Functions; The Schwarz Reflection Principle; Harnack's Principle; The Dirichlet Problem; The General Solution of the Dirichlet Problem. **8.** Infinite Series and Products: Basic Concepts; The Weierstrass Factorization Theorem; Weierstrass and Mittag-Leffler Theorems; Normal Families. **9.** Analytic Continuation: Definition of an Analytic Function Element; Analytic Continuation along a Curve; The Monodromy Theorem; The Idea of a Riemann Surface; Picard's Theorems. Glossary of Terms.

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Mathematics People

Tao Receives 2008 Waterman Award

TERENCE TAO of the University of California, Los Angeles, has received the Alan T. Waterman Award from the National Science Foundation. Called a "supreme problem-solver" and named one of "the Brilliant 10" scientists by *Popular Science* (October 2006), Tao's extraordinary work, much of which has been funded by NSF through the years, has had a tremendous impact across several mathematical areas.

The annual Waterman Award recognizes an outstanding young researcher in any field of science or engineering supported by NSF. Candidates may not be more than thirty-five years old, or seven years beyond receiving a doctorate, and must stand out for their individual achievements. In addition to a medal, the awardee receives a grant of US$500,000 over a three-year period for scientific research or advanced study in their field.

Terence Tao was born in Adelaide, Australia, in 1975. His genius in mathematics began early in life. He started to learn calculus when he was seven years old, at which age he began high school; by the age of nine he was already very good at university-level calculus. By the age of eleven, he was thriving in international mathematics competitions. Tao was twenty when he earned his doctorate from Princeton University, and he joined UCLA's faculty that year. UCLA promoted him to full professor at age twenty-four. Tao now holds UCLA's James and Carol Collins Chair in the College of Letters and Science. He is also a fellow of the Royal Society, London; the Australian Academy of Sciences (corresponding member); and the National Academy of Sciences (foreign associate). Tao's areas of research include partial differential equations, combinatorics, number theory, harmonic analysis, and algebraic geometry.

In addition to the prestigious Waterman Award, Tao has received a number of other awards, including the Salem Prize (2000), the AMS Bôcher Prize (2002), the Fields Medal (2006), the SASTRA Ramanujan Prize (2006), a MacArthur Fellowship (2006), and the Ostrowski Prize (2007).

Previous recipients of the Waterman Award in the mathematical sciences are: Emmanuel Candès (2006), Gang Tian (1994), Herbert Edelsbrunner (1991), Edward Witten (1986), Harvey M. Friedman (1984), William Thurston (1979), and Charles Fefferman (1977).

—From an NSF news release

Mitrea Awarded Michler Prize

IRINA MITREA of the University of Virginia has been awarded the Ruth I. Michler Memorial Prize. The prize, given by the Association for Women in Mathematics (AWM) and Cornell University, gives a midcareer woman mathematician a residential fellowship in the Cornell University mathematics department without teaching duties.

Mitrea earned her Ph.D. from the University of Minnesota, where she investigated the spectral properties of elliptic layer potentials under the direction of Carlos Kenig and Mikhail Safonov. She was a postdoctoral member of the Institute for Advanced Study in Princeton in 2000–2001, then was appointed assistant professor at Cornell University. She has been affiliated with the University of Virginia since 2004, becoming an associate professor in 2007. She has organized several mathematics programs for girls and serves as a mathematics consultant for the Young Women Leaders Program at the University of Virginia. Her research combines harmonic analysis techniques and partial differential equations methods.

The Michler Prize is awarded annually to a woman who has been recently promoted to the rank of associate professor or an equivalent position in the mathematical sciences. The 2008 award consists of US$42,000, with an additional travel allowance provided by Cornell University.

—From an AWM announcement

Papageorgiou Awarded 2008 Information-Based Complexity Prize

ANARGYROS PAPAGEORGIOU of Columbia University has been awarded the 2008 Information-Based Complexity Prize. The prize consists of US$3,000 and a plaque. The award will be presented at the Seminar on Algorithms and Complexity for Continuous Problems, Schloss Dagstuhl, Germany, in September 2009.

This annual prize is given for outstanding contributions to information-based complexity.

—Joseph Traub, Columbia University

Goldwasser Receives Athena Award

SHAFI GOLDWASSER of the Massachusetts Institute of Technology and the Weizmann Institute of Science, Israel, has been named the recipient of the 2008–2009 Athena Award of the Association for Computing Machinery's Committee on Women in Computing (ACM-W).

According to the citation, Goldwasser was selected "for her outstanding research contributions to cryptography, complexity theory, and number theory". She is the coinventor of zero-knowledge proofs, "a key tool in the design of cryptographic protocols. Her work on interactive and zero-knowledge proofs provides underpinnings for secure transmission of information over the Internet."

The Athena Award, which celebrates women researchers who have made fundamental contributions to computer sicence, includes an honorarium of US$10,000, provided by Google Inc.

—From an ACM announcement

Bridgeland and Tong Receive Adams Prize

TOM BRIDGELAND of the University of Sheffield and DAVID TONG of the University of Cambridge have been jointly awarded the Adams Prize by the University of Cambridge. The selected topic for 2008 was quantum fields and strings. According to the prize citation, Bridgeland "has made highly original, deep and wide-ranging contributions to two branches of algebraic geometry, classical and noncommutative, of which a new synthesis has been stimulated by recent developments in string theory." Tong "has made strikingly original advances across a broad range of topics in both quantum field theory and string theory, a particularly notable contribution being to use the D-branes of string theory to understand certain supersymmetric solitons arising in field theory; his work has implications for cosmology as well as quantum physics."

The Adams Prize is awarded each year by the Faculty of Mathematics and St. John's College to a young researcher based in the United Kingdom who is doing first-class international research in the mathematical sciences. The prize is named after the mathematician John Couch Adams and was endowed by members of St. John's College. It is currently worth £13,500 (approximately US$26,500), of which one-third is awarded to the prizewinner on announcement of the prize; one-third is provided to the prizewinner's institution (for research expenses of the prizewinner); and one-third is awarded to the prizewinner on acceptance for publication in an internationally recognized journal of a substantial (normally at least twenty-five printed pages) original survey article of which the prizewinner is an author.

—From a University of Cambridge announcement

Griffiths Awarded Brouwer Prize

PHILLIP A. GRIFFITHS of the Institute for Advanced Study in Princeton has been awarded the 2008 L. E. J. Brouwer Prize of the Royal Dutch Mathematical Society (Koninklijk Wiskundig Genootschap, KWG). He was honored for his work in complex algebraic geometry and differential geometry, including research on algebraic cycles and variations of Hodge structures. He will present the Brouwer Lecture during the European Congress of Mathematics in Amsterdam in July 2008.

The Brouwer Prize is the Netherlands' most prestigious award in mathematics. It was established shortly after the death of the distinguished mathematician L. E. J. Brouwer and is awarded every three years. For each award the Society chooses an important field in mathematics; the 2008 prize was awarded in the field of geometry.

—Herman te Riele, Centrum voor Wiskunde en Informatica

Heller Awarded Templeton Prize

MICHAEL HELLER, a Polish cosmologist and Catholic priest who for more than forty years has developed sharply focused and strikingly original concepts on the origin and cause of the universe, often under intense governmental repression, has won the 2008 Templeton Prize. The prize is valued at £820,000, more than US$1.6 million, and is the world's largest annual monetary award given to an individual.

Heller, 72, professor in the faculty of philosophy at the Pontifical Academy of Theology in Cracow, toiled for years beneath the stifling strictures of the Soviet era. He has become a compelling figure in the realms of physics and cosmology, theology, and philosophy with his cogent and provocative concepts on issues that all of these disciplines pursue, albeit from often vastly different perspectives.

With an academic and religious background that enables him to comfortably and credibly move within each of these domains, Heller's extensive writings have evoked new and important consideration of some of humankind's most profound concepts.

Heller's examination of fundamental questions such as "Does the universe need to have a cause?" engages a wide range of sources who might otherwise find little in common. By drawing together mathematicians, philosophers, cosmologists, and theologians who pursue these topics, he also allows each to share insights that may edify the other without any violence to their respective methodologies.

In a statement prepared for the news conference, Heller described his position as follows: "Various processes in the universe can be displayed as a succession of states in such a way that the preceding state is a cause of the succeeding one…(and) there is always a dynamical law prescribing how one state should generate another state. But dynamical laws are expressed in the form of mathematical equations, and if we ask about the cause of the universe we should ask about a cause of mathematical laws. By doing so we are back in the Great Blueprint of God's thinking the universe, the question on ultimate causality…: 'Why is there something rather than nothing?' When asking this question, we are not asking about a cause like all other causes. We are asking about the root of all possible causes."

Heller's current work focuses on noncommutative geometry and groupoid theory in mathematics, which attempts to remove the problem of an initial cosmological singularity at the origin of the universe. "If on the fundamental level of physics there is no space and no time, as many physicists think," says Heller, "noncommutative geometry could be a suitable tool to deal with such a situation."

Heller plans to dedicate the Templeton Prize money to help create the Copernicus Center in conjunction with Jagiellonian University and the Pontifical Academy of Theology in Cracow to further research and education in science and theology as an academic discipline.

—From a Templeton Foundation news release

Ziegler Wins Communicator Award

GÜNTER M. ZIEGLER of the Technische Universität Berlin has been named the recipient of the 2008 Communicator Award given by the Deutsche Forschungsgemeinschaft (DFG; German Research Foundation) and the Donors' Association for the Promotion of Sciences and Humanities in Germany. He was selected "in recognition of his outstanding ability to communicate his research work in discrete mathematics to the general public in a fresh and innovative way."

According to the citation, Ziegler is a "young and unconventional scientist who has succeeded in making a positive impact on the public image and public perception of mathematics, which is still often misunderstood and unpopular.…Ziegler has been actively approaching the public and the media for about ten years, in his endeavors to communicate the importance of mathematics and his particular field, discrete geometry, in a comprehensible manner. In doing so, he has used forms and formats that are not only unusual, but also highly effective, some of which he developed personally. His 'Math Quiz' and 'Science Café', in which he engages in dialogue with scientists from other disciplines, have enjoyed particular success. These events, which regularly attract an audience in the hundreds, are accompanied by numerous articles and columns in newspapers and magazines as well as appearances on radio and television."

The Communicator Award is given to scientists and researchers who have conveyed their research findings to the general public in a particularly varied, original, or creative manner and who have rendered outstanding services to the increasingly important dialogue between the scientific community and the public.

—From a DFG announcement

Buchberger Receives ACM Award

BRUNO BUCHBERGER of Johannes Kepler University, Linz, Austria, has been named the recipient of the Paris Kanellakis Theory and Practice Award of the Association for Computing Machinery (ACM). He was recognized "for his role in developing the theory of Groebner Bases, which has become a crucial building block to computer algebra and is widely used in science, engineering, and computer science." His work "has resulted in automated problem-solving tools to address challenges in robotics, computer-aided design, systems design, and modeling biological systems."

The Paris Kanellakis Theory and Practice Award honors specific theoretical accomplishments that have had a significant and demonstrable effect on the practice of computing. This award is endowed by contributions from the Kanellakis family, with additional financial support provided by ACM's Special Interest Groups on Algorithms and Computational Theory, on Design Automation, on Management of Data, and on Programming Languages; the ACM SIG Project Fund; and individual contributions.

—From an ACM announcement

Lester and Reys Recognized for Lifetime Achievement in Mathematics Education

FRANK K. LESTER JR. of Indiana University, Bloomington, and ROBERT E. REYS of the University of Missouri are the recipients of 2008 Mathematics Education Trust (MET) Lifetime Achievement Awards for Distinguished Service to Mathematics Education awarded by the National Council

of Teachers of Mathematics (NCTM). They were selected in recognition of their accomplishments in leadership, teaching, and service to mathematics education.

Lester is well known for his research on mathematical problem-solving instruction and his work in mathematics learning, teaching, and curriculum. He has served as a member of NCTM's Board of Directors, Research Advisory Committee, and Standards Impact Research Group and as editor of the *Journal for Research in Mathematics Education*. He organized and participated in the Research Catalyst Conference sponsored by NCTM and the National Science Foundation and has served on a steering committee of the American Educational Research Association special interest group for research in mathematics education. According to the citation, "Lester's work demonstrates his commitment to transforming research results into practice."

Reys's contributions to mathematics education include studies of number sense, calculator use, and estimation in elementary school mathematics. He has been an adviser for "Research within Reach" for elementary and secondary school mathematics. He has served as general editor of five yearbooks and coeditor of a sixth for NCTM and was a member of one of the first NCTM interpretive teams that examined, summarized, and reported results from the National Assessment of Educational Progress in mathematics. (Editor's Note: Reys is a frequent contributor to the *Notices*. His most recent article, "Jobs in mathematics education in institutions of higher education in the United States", appeared in the June/July 2008 issue.)

—From an NCTM announcement

USA Mathematical Olympiad

The 2008 USA Mathematical Olympiad (USAMO) was held April 29 and 30, 2008. The students who participated in the Olympiad were selected on the basis of their performances on the American High School and American Invitational Mathematics Examinations. The twelve highest scorers in the USAMO, listed in alphabetical order, were: DAVID BENJAMIN, West Lafayette, Indiana; TAORAN CHEN, Fresh Meadows, New York; PAUL CHRISTIANO, Saratoga, California; SAMUEL ELDER, Fort Collins, Colorado; SHAUNAK KISHORE, West Chester, Pennsylvania; DELONG MENG, Baton Rouge, Louisiana; EVAN O'DORNEY, Danville, California; QINXUAN PAN, Gaithersburg, Maryland; DAVID ROLNICK, Rupert, Vermont; COLIN SANDON, Essex Junction, Vermont; KRISHANU SANKAR, Hastings-on-Hudson, New York; and ALEX ZHAI, Champaign, Illinois.

In June the twelve USAMO winners will take the team selection test to qualify for the U.S. team. The six students with the highest combined scores from the test and the USAMO will attend the Mathematical Olympiad Summer Program (MOSP) at the University of Nebraska, Lincoln, training to compete in the International Mathematical Olympiad (IMO) to be held in Madrid, Spain, July 10–22, 2008.

—Elaine Kehoe

Moody's Mega Math Challenge Winners Announced

The winners of the 2008 Mega Math Challenge for high school students have been announced. The topic for this year's competition was "Energy Independence Meets the Law of Unintended Consequences: Is Ethanol the Answer?" A team from the High Technology High School in Lincroft, New Jersey, was awarded the Summa Cum Laude Team Prize of US$20,000 in scholarship money. The members of the team were THOMAS JACKSON, KELLY ROACHE, AFANASIY YERMAKOV, and JASON ZUKUS. The team's coach was Raymond Eng, and the title of their project was "Ethanol: Not All It Seems to Be".

The Magna Cum Laude Team Prize of US$15,000 was awarded to a team from Manalapan High School, Manalapan, New Jersey. The team members were MICHAEL BACSIK, JEPHTHAH LIDDIE, JOSHUA NEWMAN, THOMAS SOZZI, and KEVIN TIEN. The team's coach was Jessy Friedman, and the title of their project was "Going Green Does Not Save Green: Corn-Based Ethanol and U.S. Energy Independence".

The Cum Laude Team Prize of US$10,000 in scholarship money was awarded to a team from Shrewsbury High School, Shrewsbury, Massachusetts, for their project "Unintended Consequences: The Ethanol Corn-Nundrum". The team members were ANAND DESAI, RUBY LEE, SHENGZHI LI, ANIRVAN MUKHERJEE, and LINGKE WANG, and they were coached by Catherine McDonough.

A team from Holmdel High School, Holmdel, New Jersey, won the Meritorious Team Prize of US$7,500 for their project "The Hidden Costs of Ethanol". The team consisted of ERIC CHUNG, ALAAP PARIKH, and ASHUTOSH SINGHAL and was coached by Josephine Blaha.

The Exemplary Team Prize of US$5,000 went to a team from Hunterdon Central Regional High School in Flemington, New Jersey. The team members were BRANDON COMELLA, GAWAIN LAU, KELVIN MEI, NEVIN RAJ, and YIWEN ZHAN, and their coach was David Gelb. Their project was titled "Ethanol: The Future of America's Energy Independence?".

The First Honorable Mention Team Prize of US$2,500 went to a team from the Wheeler School in Providence, Rhode Island, for a project titled "Ethanol—Too Good To Be True?". The team members were BRETT MUSCO, CAMERON MUSCO, CHRISTOPHER MUSCO, CHRISTOPHER SHAW, and KARAN TAKHAR, and they were coached by George Lewis.

The Mega Math Challenge invites teams of high school juniors and seniors to solve an open-ended, realistic, challenging modeling problem focused on real-world issues. The top five teams receive awards ranging from US$5,000 to US$20,000 in scholarship money. The competition is sponsored by the Moody's Foundation, a charitable foundation established by Moody's Corporation, and organized by the Society for Industrial and Applied Mathematics (SIAM).

—Elaine Kehoe

National Academy of Sciences Elections

The National Academy of Sciences (NAS) has announced the election of seventy-two new members and eighteen foreign associates. Following are the new members who work in the mathematical sciences: EMILY A. CARTER, Princeton University; HELMUT HOFER, Courant Institute of Mathematical Sciences, New York University; PETER W. JONES, Yale University; FRANK T. LEIGHTON, Massachusetts Institute of Technology; THOMAS M. LIGGETT, University of California, Los Angeles; NATHAN SEIBERG, Institute for Advanced Study; and ELIZABETH A. THOMPSON, University of Washington, Seattle. Elected as foreign associates were H. KEITH MOFFATT, University of Cambridge, and TERENCE C. TAO, University of California, Los Angeles.

—From an NAS announcement

American Academy Elections

Twelve mathematical scientists have been elected to membership in the American Academy of Arts and Sciences for 2008. They are: RUZENA BAJCSY, University of California, Berkeley; EMILY A. CARTER, Princeton University; SUN-YUNG ALICE CHANG, Princeton University; TOBIAS COLDING, Massachusetts Institute of Technology; VLADIMIR DRINFELD, University of Chicago; DAVID GOTTLIEB, Brown University; JOHN GUCKENHEIMER, Cornell University; LARRY V. HEDGES, Northwestern University; RICHARD H. HERMAN, University of Illinois, Urbana-Champaign; DAVID KAZHDAN, Hebrew University, Jerusalem, and Harvard University; JAMES H. SIMONS, Renaissance Technologies; and CHARLES SIMONYI, Intentional Software Corporation.

The American Academy of Arts and Sciences was founded in 1780 to foster the development of knowledge as a means of promoting the public interest and social progress. The membership of the academy is elected and represents distinction and achievement in a range of intellectual disciplines—mathematical and physical sciences, biological sciences, social arts and sciences, and humanities and fine arts.

—From an AAAS announcement

Juha Heinonen (1960–2007)

University of Michigan professor of mathematics Juha Heinonen passed away on October 30, 2007, after a courageous battle with kidney cancer. He was born July 23, 1960, in the small town of Toivakka in central Finland. His father was a lumberjack and well-respected socialist politician for the tiny town. A gifted athlete, Heinonen was the 1976 Finnish national champion in his class in 5-kilometer cross-country skiing. After serving one year in the Finnish army, he enrolled as a student of mathematics at the University of Jyväskylä. His 1987 Ph.D. thesis, directed by Olli Martio, was in nonlinear potential theory.

Heinonen first came to the University of Michigan for a semester as a visiting graduate student in 1985. In 1988 he returned as a three-year postdoctoral assistant professor, and in 1992 he accepted a tenure-track assistant professorship. In 2000 he was promoted to professor.

Considered a scholar of high professional standards, Heinonen was a leading figure in geometric function theory, his main research area. His two books, *Nonlinear Potential Theory of Degenerate Elliptic Equations* (coauthored with T. Kilpeläinen and O. Martio) and *Analysis on Metric Spaces*, have become standard references in their fields. He coauthored more than 60 research papers, many of which contributed to the creation of a new branch of mathematics, now called analysis on metric spaces. Heinonen was a generous and enthusiastic collaborator who was proud of the fact that nearly all of his research publications were joint works. His collaborators admired him for his erudition, his deep mathematical insights, and his never-ending scientific curiosity.

Heinonen directed eight doctoral students, and many students, junior faculty, and young researchers greatly benefited from his patient mentorship and wise tutelage. His expertise was recognized with many awards and fellowships, including a Sloan Fellowship, numerous NSF grants, several visiting appointments, and an Excellence in Research Award from the University of Michigan. For seven years he was an editor of the *Proceedings of the AMS*. In 2002 he was invited to give a talk at the International Congress of Mathematicians in Beijing. He became a member of the Finnish Academy of Science and Letters in 2004.

In 1991 Heinonen married mathematician Karen Smith, who is also a professor at the University of Michigan. They had a daughter, Sanelma, in 1998, and their boy-girl twins, Tapio and Helena, in 2003. Juha was a vibrant, balanced, satisfied person who enjoyed many things in life besides mathematics and sports. He spent his free time studying foreign languages or reading history, biographies, and political commentary. He also loved the outdoors.

Besides his wife and children, Heinonen is survived by his mother, Liisa Heinonen, and his sister, Maritta Nukarinen. Further information is available at `http://www.math.lsa.umich.edu/events/juhaMem.html`.

—From a University of Michigan Department of Mathematics obituary

Murray H. Protter (1918–2008)

Murray H. Protter, a mathematician and former chair of the mathematics department at the University of California at Berkeley, died on May 1, 2008, in Berkeley. He was ninety. The cause was congestive heart failure.

Murray Protter had a great impact on the field of mathematics in the U.S. and internationally, not just from his research achievements involving maximum principles and partial differential equations but also from his leadership skills and his gift for teaching. He had the good fortune to be department chair of the UC Berkeley mathematics

department during the early 1960s, which was shortly after the Soviet Union launched the satellite Sputnik in 1958. During this time it became a national priority to improve science education, and Protter helped to hire many of the great mathematicians of the day, turning Berkeley into one of the best mathematics departments in the U.S. and indeed worldwide. He was also active in the AMS, serving for many years as its treasurer, and also was a longtime editor of the book reviews of the *Bulletin of the AMS*.

Protter was the author of many books, the most famous one written jointly with C. B. Morrey Jr., *Calculus with Analytic Geometry: A First Course*, which was published in 1964. It became the second best-selling text in calculus in the U.S. The research book of which he was the most proud was *Maximum Principles in Differential Equations*, written jointly with Hans Weinberger and first published in 1967. It was reissued by Springer-Verlag in 1999.

Protter joined the Second World War effort after earning his Ph.D. at Brown by calculating the flutter speeds of military aircraft. After this work he joined the faculty at Syracuse University, later moving to the Institute for Advanced Study in Princeton and then to Berkeley, where he remained. At Berkeley he enjoyed a leadership position for many years and was chosen to lead a delegation of mathematicians to the Soviet Union as part of a cultural exchange at the beginning of the period of détente, commonly considered to be the years 1969–1976.

Protter also lent his hand to industry from time to time. One example concerns a time when Shell Oil was drilling for oil and not finding any. Finding the location of oil involved solving the wave equation with certain boundary conditions. This is usually done using computer algorithms, but the drill holes were coming up dry. Protter showed that the wave equation Shell Oil was using had no solution and gave the company the correct formulation of the equation.

Protter grew up in Brooklyn, attended the University of Michigan, and earned his Ph.D. at Brown University in 1946. It was there he met his wife, Ruth Rotman Protter, who survives him. Their first child, Barbara (now of Kansas City), was born in Providence, and then they moved to Syracuse, where his second child, Philip (now of Ithaca), was born. He leaves four grandchildren and three great grandchildren.

—Philip Protter, Cornell University

Correction

The May 2008 issue of the *Notices* carried an article about the 2008 prizes of the Association for Women in Mathematics (AWM). The article erroneously stated that the AWM Shafer Prize winner, Alison Miller, was the first woman to receive a gold medal in the International Mathematical Olympiad (IMO). In fact, Miller is the first female member of the United States IMO team to have won a gold medal, which she received in 2004. In 2007 another woman member of the U.S. team, Sherry Gong, also won a gold medal. The first woman ever on a U.S. team was Melanie Wood, who was on the team in 1998 and 1999 and won silver medals both times. She also received the AMS-MAA-SIAM Morgan Prize in 2004 and the Schafer Prize in 2002.

A brief examination of information on the Internet appears to indicate that the woman who has won the most gold medals in the IMO is Evgenia Malinnikova, who was on the Russian team and won gold medals in 1989, 1990, and 1991. She was also the top IMO competitor at that time, as she came within one point of having three perfect scores in a row (perfect scores are much rarer than gold medals). Also noteworthy are Maryam Mirzakhani, who as a member of the Iranian team received gold medals in 1994 and 1995, and Ana Caraiani, who was on the Romanian team and received gold medals in 2002 and 2003. Caraiani was the Schafer Prize winner in 2007.

—Allyn Jackson

Mathematics Opportunities

DMS Opens New Institute Competition

The Division of Mathematical Sciences (DMS) of the National Science Foundation supports a number of institutes through its Mathematical Sciences Research Institutes program. The goals of this program include advancing research in the mathematical sciences, increasing the impact of the mathematical sciences in other disciplines, enabling the mathematical sciences to respond to national needs, and expanding the talent base engaged in mathematical research in the United States. Institutes have proven to be an effective means of achieving these goals. The program goes back to 1980, when two institutes were established; since then, the portfolio of institutes has been expanded as a result of competitions held in 1997, 2001, 2004, and 2006.

DMS now supports programs at seven U.S.-based institutes: the American Institute of Mathematics (AIM) in Palo Alto, California; the Institute for Advanced Study (IAS) in Princeton, New Jersey; the Institute for Mathematics and its Applications (IMA) in Minneapolis, Minnesota; the Institute for Pure and Applied Mathematics (IPAM) in Los Angeles, California; the Mathematical Biosciences Institute (MBI) in Columbus, Ohio; the Mathematical Sciences Research Institute (MSRI) in Berkeley, California; and the Statistical and Applied Mathematical Sciences Institute (SAMSI) in Research Triangle Park, North Carolina. The level of support varies among the institutes, and several institutes have programs other than those supported by DMS.

The mathematical sciences have gone through a period of spectacular growth and excitement. New ideas have been developed, some significant long-standing open problems have been solved, and unification has replaced fragmentation as the dominant trend in the discipline. At the same time, the mathematical sciences have been embraced as an enabling technology in many areas of application, from the physical sciences and engineering to the life sciences and finance. The mathematical sciences research institutes have played a transformative role in these developments, and this role is expected to grow even more as the mathematical sciences reach out to new areas of human activity.

In anticipation of this increasing role, DMS is soliciting proposals from the community for institutes with clearly defined imaginative missions that match the objectives of the DMS Mathematical Sciences Research Institutes program. DMS encourages prospective applicants to consider the structure of the mathematical sciences research institutes currently supported by the division and, where appropriate, consider alternative structures that complement the existing ones and increase the potential to further transform the mathematical sciences landscape.

The program solicitation is available on the Web at `http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5302`. The deadline for proposals is **February 27, 2009**.

—From a DMS announcement

NSF Focused Research Groups

The Focused Research Groups (FRG) activity of the Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF) supports small groups of researchers in the mathematical sciences.

The DMS has announced deadline dates for the fiscal year 2008 competition for FRG grants. The deadline for receipt of the required letters of intent to submit FRG proposals is **August 15, 2008**. The deadline date for full proposals is **September 19, 2008**. The FRG solicitation may be found on the Web at `http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5671&org=DMS`.

—From an NSF announcement

NSF Mathematical Sciences Postdoctoral Research Fellowships

The Mathematical Sciences Postdoctoral Research Fellowship program of the Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF) awards fellowships each year for research in pure mathematics, applied mathematics and operations research, and statistics. The deadline for this year's applications is **October 15, 2008**. Applications must be submitted via FastLane on the World Wide Web. For more information see the website `http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5301&org=DMS`.

—From an NSF announcement

NSF CAREER Program Guidelines Available

The guidelines for the Faculty Early Career Development (CAREER) Program of the National Science Foundation (NSF) are now available on the World Wide Web. The program solicitation number is 08-557. Information is available at `http://nsf.gov/pubs/2008/nsf08557/nsf08557.htm`. The deadline for submission of proposals is **July 24, 2008**.

—From an NSF announcement

NSA Mathematical Sciences Grants and Sabbaticals Program

As the nation's largest employer of mathematicians, the National Security Agency (NSA) is a strong supporter of the academic mathematics community in the United States. Through the Mathematical Sciences Program, the NSA provides research funding and sabbatical opportunities for eligible faculty members in the mathematical sciences.

Grants for Research in Mathematics. The Mathematical Sciences Program (MSP) supports self-directed, unclassified research in the following areas of mathematics: Algebra, Number Theory, Discrete Mathematics, Probability, and Statistics. The MSP also supports conferences and workshops (typically in the range of US$12,000–$15,000) in these five mathematical areas. The program does not entertain research or conference proposals that involve cryptology. Research support may include summer salary for faculty members, a modest amount for graduate student support, travel assistance, and other miscellaneous expenses. Proposals that involve participation by women and other individuals from underrepresented backgrounds are encouraged.

Principal investigators, graduate students, consultants, and all other personnel supported by NSA grants must be U.S. citizens or permanent residents of the United States at the time of proposal submission.

Please note that the Mathematical Sciences Program is no longer using a hard-copy submission system. Proposals must be submitted **electronically** by **October 15, 2008**, via the program website: `http://www.nsa.gov/msp/index.cfm`. Details on the submission process are forthcoming. Please check the website often for updates.

Sabbatical Program. NSA's Mathematics Sabbatical Program offers mathematicians, statisticians, and computer scientists the unique opportunity to develop skills in directions that would be nearly impossible anywhere else. Sabbatical employees work side by side with other NSA scientists on projects that involve cryptanalysis, coding theory, number theory, discrete mathematics, statistics and probability, and many other subjects. Visitors spend 9–24 months at NSA and most find that within a very short period of time they are able to make significant contributions.

NSA pays 50 percent of salary and benefits during academic months and 100 percent of salary and benefits during summer months of the sabbatical detail. A monthly housing supplement is available to help offset the cost of local lodging. On average, three sabbatical positions are available per year.

Applicants must be U.S. citizens and must be able to obtain a security clearance. Applications should be submitted **electronically** by **November 15, 2008**, via the Sabbatical Program website: `http://www.nsa.gov/msp/index.cfm`. Sabbatical details typically start by September of the following year.

A complete application includes cover letter and curriculum vitae with list of significant publications. The cover letter should describe the applicant's research interests, programming experience and level of fluency, and how an NSA sabbatical would affect teaching and research upon return to academia. For more detailed application information, please consult the program website.

For more information about the Grants or Sabbaticals Program, please contact the program office at 301-688-0400. You may also write to the program director, Michelle Wagner (`mdwagn4@nsa.gov`), or to the program administrator, Barbara Johnson (`bajohn1@nsa.gov`).

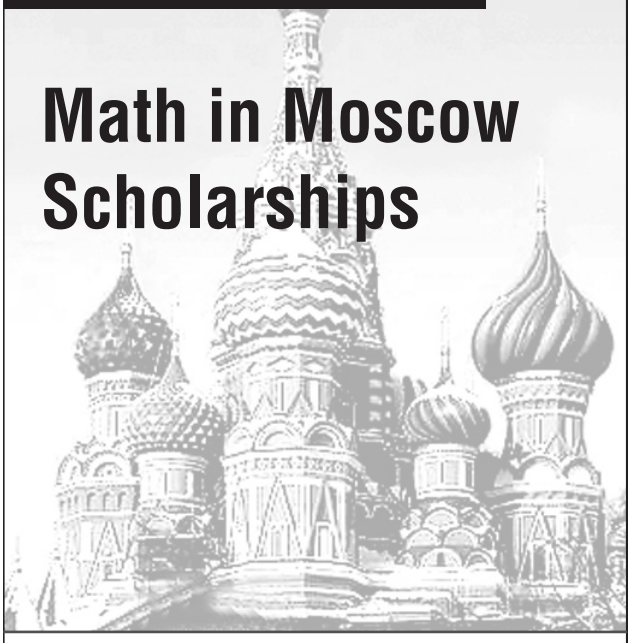
—Mathematical Sciences Program announcement

Call for Nominations for Information-Based Complexity Young Researcher Award

This annual award is given for significant contributions to information-based complexity by a young researcher. The prize consists of US$1,000 and a plaque. Any researcher who has not reached his or her thirty-fifth birthday by September 30 in the year of the award is eligible. A person does not have to be nominated to win the award.

AMERICAN MATHEMATICAL SOCIETY

Math in Moscow Scholarships



The AMS invites undergraduate mathematics and computer science majors in the U.S. to apply for a special scholarship to attend a Math in Moscow semester at the Independent University of Moscow. Funding is provided by the National Science Foundation and is administered by the AMS.

The Math in Moscow program offers a unique opportunity for intensive mathematical study and research, as well as a chance for students to experience life in Moscow. Instruction during the semester emphasizes in-depth understanding of carefully selected material: students explore significant connections with contemporary research topics under the guidance of internationally recognized research mathematicians, all of whom have considerable teaching experience in English.

The application deadline for spring semesters is September 30, and for fall semesters is April 15.

For more information, see www.ams.org/employment/mimoscow.html.

Contact: Membership and Programs Department, American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294, USA; telephone: 800-321-4267, ext. 4170; email: student-serv@ams.org.

AMS
American Mathematical Society
www.ams.org

The members of the award committee are Jakob Creutzig, TU Darmstadt, Germany; Andreas Neuenkirch, University of Frankfurt, Germany; Dirk Nuyens, Katholieke Universiteit, Leuven, Belgium; Friedrich Pillichshammer, University of Linz, Austria; Joseph F. Traub, Columbia University; and Henryk Wozniakiowski, Columbia University and University of Warsaw, Poland.

The deadline for nominations for the award is **September 30, 2008**. Nominations should be sent to Joseph Traub. The award can be given for work done in a single year or a number of years. The work can be published in any journal, number of journals, or monograph.

—Joseph F. Traub, Columbia University

News from the CIRM Trento

The Centro Internazionale per la Ricerca Matematica (CIRM) in Trento, Italy, is seeking applications for visiting positions and for scholars to perform research in pairs.

Applications are sought for both visiting scholar and visiting professor positions. Visiting scholars will perform mathematical research in cooperation with scientists and researchers at Trento University or in the Trento area and will give some research seminars. Visiting professors will give short Ph.D. courses, summer courses, or series of seminars. Applications must specify proposed dates for the visit (usually between fifteen days and three months). Applications and proposals may be sent at any time and are reviewed three times a year.

The Research in Pairs (RIP) program supports two or three partners from different universities in working on a specific research project for a specified period of time (ranging from one to six weeks). Applicant partners must submit a scientific project in mathematics, with a detailed research program that results in one or more scientific publications in journals of excellent mathematical quality. Participants will also give occasional research seminar talks at the CIRM or at the University of Trento. Applications can be submitted at any time, but preferably a few months before the planned stay to allow sufficient time for the decision process.

The CIRM also has postdoctoral fellowships for 2008–2009, the deadline for which will have passed by the time this issue of the *Notices* reaches its readers. Information about the next round of fellowships will be posted on the CIRM website.

Applications for visiting professorships and for the RIP program should be sent by postal mail to Fondazione Bruno Kessler (FBK), Centro Internazionale per la Ricerca Matematica, Via Sommarive n. 14-Povo, 38100 Trento, Italy, or by email to `micheletti@fbk.eu`. For more information, see the CIRM website: `http://www.itc.it/altri/Renderer.aspx?targetID=215`.

—Augusto Micheletti, CIRM

Inside the AMS

From the AMS Public Awareness Office

• ***Mathematical Moments* Podcasts.** Recently added to the *Mathematical Moments* site is a four-part podcast interview with Ken Golden about his research into sea ice. Hear this and other interviews with experts at http://www.ams.org/mathmoments.

• **Headlines & Deadlines for Students.** Students and faculty advisors may sign up to receive monthly email notifications of news, helpful websites, special programs, and deadlines for applications for fellowships and grants, meeting registrations, and more. The *Headlines & Deadlines for Students* webpage is updated on a regular basis at http://www.ams.org/news-for-students/.

• **This Mathematical Month–August.** Read about events that occurred in the month of August, such as ICM 1966, the Chicago Mathematics Congress of 1893, and the dedication of the Kiiti Morita Gardens at the AMS headquarters in 1998, at http://www.ams.org/ams/thismathmonth-aug.html.

—Annette Emerson and Mike Breen
AMS Public Awareness Officers
paoffice@ams.org

Ken Golden working on sea ice.

Math in Moscow Scholarships Awarded

The AMS has made awards to four mathematics students to attend the Math in Moscow program in the fall of 2008. Following are the names of the undergraduate students and their institutions: SAMANTHA GOTTLIEB, Wesleyan University; ROBERT LAZAR, University of California Irvine; OLGA MANDELSHTAM, California Institute of Technology; and TIMOTHY RUSSELL, Eastern Illinois University. Each student has been awarded a scholarship of US$7,500.

Math in Moscow is a program of the Independent University of Moscow that offers foreign students (undergraduate or graduate students specializing in mathematics and/or computer science) the opportunity to spend a semester in Moscow studying mathematics. All instruction is given in English. The fifteen-week program is similar to the Research Experiences for Undergraduates programs that are held each summer across the United States.

Since 2001, each semester the AMS has awarded several scholarships for U.S. students to attend the Math in Moscow program. The scholarships are made possible through a grant from the National Science Foundation. For more information about Math in Moscow, consult http://www.mccme.ru/mathinmoscow and the article "Bringing Eastern European mathematical traditions to North American students", *Notices*, November 2003, pages 1250–4.

—Elaine Kehoe

AMS Honors Mathematics Teachers

The American Mathematical Society (AMS) hosted a breakfast to honor the Presidential Awardees for Excellence in Mathematics Teaching as part of recognition week activities held in May 2008 for mathematics and science teachers from across the U.S.

The Presidential Awards for Excellence in Mathematics and Science Teaching (PAEMST) program is administered for the White House by the National Science Foundation

and annually chooses one outstanding teacher in both mathematics and science from each state and the District of Columbia. It is the nation's highest honor for teaching in these fields. The 2007 winning teachers were selected from among the nation's finest secondary school mathematics and science teachers and each received a US$10,000 educational grant in addition to a weeklong, all-expense-paid trip to Washington DC to particiate in the awards ceremony, professional development sessions, and other celebratory events.

The AMS is proud to recognize the outstanding achievements of these exceptional mathematics teachers and congratulates all the awardees on their accomplishments.

For more information on the Presidential Awards, please visit `http://www.paemst.org`.

—Anita Benjamin, AMS Washington Office

Deaths of AMS Members

WILLIAM J. BARR, from Park Ridge, IL, died on April 17, 1994. Born on February 5, 1919, he was a member of the Society for 51 years.

HERBERT S. BEAR, from Honolulu, HI, died on December 22, 2007. Born on March 13, 1929, he was a member of the Society for 50 years.

MELVYN S. BERGER, professor from the University of Massachusetts, Amherst, died on October 1, 2005. Born on August 23, 1939, he was a member of the Society for 41 years.

BARBARA CALDWELL BROBECK, from Washington, DC, died on November 7, 2007. Born on September 19, 1926, she was a member of the Society for 38 years.

FRANCIS R. BUIANOUCKAS, professor emeritus from Bronx Community College (CUNY), died on April 27, 2004. Born on September 29, 1941, he was a member of the Society for 32 years.

Y. W. CHEN, professor emeritus from the University of Massachusetts, Amherst, died on February 5, 1995. Born on April 1, 1910, he was a member of the Society for 50 years.

ALLEN DEVINATZ, professor emeritus from Northwestern University, died on February 5, 2008. Born on July 22, 1922, he was a member of the Society for 58 years.

DONALD FORBES, retired from J. P. Morgan Investment Management, died on August 16, 2007. Born on May 28, 1916, he was a member of the Society for 46 years.

NORMAN S. FREE, from Cherry Hill, NJ, died on January 10, 2008. Born on August 3, 1915, he was a member of the Society for 62 years.

MARIANO GARCIA, from Davie, FL, died on November 27, 2007. Born on September 13, 1918, he was a member of the Society for 65 years.

FRANK F. GUCKER, from Anderson, SC, died on February 14, 2008. Born on April 18, 1926, he was a member of the Society for 43 years.

ALEX HELLER, professor emeritus from the Graduate School and University Center (CUNY), died on January 31, 2008. Born on July 9, 1925, he was a member of the Society for 61 years.

GILBERT HUNT, retired from Princeton University, died on June 6, 2008. Born on March 4, 1916, he was a member of the Society for 58 years.

EUGENE ISAACSON, professor emeritus from New York University, Courant Institute, died on March 31, 2008. Born on June 14, 1919, he was a member of the Society for 61 years.

CHARLES LEWIS KELLER, from Sun City Center, FL, died on December 31, 2007. Born on May 20, 1922, he was a member of the Society for 53 years.

CHARLES F. KOCH, from Grand Forks, ND, died on April 29, 2007. Born on March 23, 1932, he was a member of the Society for 46 years.

HOWARD LEVENE, professor emeritus from Columbia University, died on July 2, 2003. Born on January 17, 1914, he was a member of the Society for 59 years.

EUGENE LEVINE, professor from Adelphi University, died on August 26, 1995. Born on August 30, 1931, he was a member of the Society for 36 years.

VAN A. MCAULEY, retired from NASA, died on January 8, 2008. Born on August 28, 1926, he was a member of the Society for 28 years.

ERNEST C. SCHLESINGER, professor emeritus from Connecticut College, died on March 3, 2008. Born on November 25, 1925, he was a member of the Society for 59 years.

MARLOW C. SHOLANDER, from Coatesville, PA, died on July 24, 1995. Born on March 13, 1915, he was a member of the Society for 50 years.

DONALD M. SOLITAR, professor emeritus from York University, died on April 25, 2008. Born on September 5, 1932, he was a member of the Society for 54 years.

H. CHRISTINE B. STOKES, professor emerita from the University of Mississippi, died on December 28, 2007. Born on March 7, 1928, she was a member of the Society for 40 years.

FRED SUPNICK, professor emeritus from City College, CUNY, died on September 26, 2005. Born on April 15, 1915, he was a member of the Society for 65 years.

Reference and Book List

*The **Reference** section of the* Notices *is intended to provide the reader with frequently sought information in an easily accessible manner. New information is printed as it becomes available and is referenced after the first printing. As soon as information is updated or otherwise changed, it will be noted in this section.*

Contacting the *Notices*

The preferred method for contacting the *Notices* is electronic mail. The editor is the person to whom to send articles and letters for consideration. Articles include feature articles, memorial articles, communications, opinion pieces, and book reviews. The editor is also the person to whom to send news of unusual interest about other people's mathematics research.

The managing editor is the person to whom to send items for "Mathematics People", "Mathematics Opportunities", "For Your Information", "Reference and Book List", and "Mathematics Calendar". Requests for permissions, as well as all other inquiries, go to the managing editor.

The electronic-mail addresses are notices@math.ou.edu in the case of the editor and notices@ams.org in the case of the managing editor. The fax numbers are 405-325-7484 for the editor and 401-331-3842 for the managing editor. Postal addresses may be found in the masthead.

Upcoming Deadlines

July 24, 2008: Proposals for NSF Faculty Early Career Development (CAREER) Program. See "Mathematics Opportunities" in this issue.

July 31, 2008: Nominations for ICTP Ramanujan Prize. See http://prizes.ictp.it/prizes/Ramanujan/.

August 1, 2008: Applications for August review for the National Academies Postdoctoral and Senior Research Associateship Programs. See http://www7.nationalacademies.org/rap/index.html or contact Research Associateship Programs, National Research Council, Keck 568, 500 Fifth Street, NW, Washington, DC 20001; telephone 202-334-2760; fax 202-334-2759; email: rap@nas.edu.

August 15, 2008: Letters of intent for NSF Focused Research Groups. See "Mathematics Opportunities" in this issue.

August 15, 2008: Nominations for SASTRA Ramanujan Prize. See http://www.math.ufl.edu/sastra-prize/nominations-2008.html or email: sastraprizemath.ufl.edu.

August 18, 2008: Applications for NSF Research Experiences for

Where to Find It

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AMS Email Addresses—*February 2008, p. 274*

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NRC Board on Mathematical Sciences and Their Applications—*March 2008, p. 401*

NRC Mathematical Sciences Education Board—*April 2008, p. 515*

NSF Mathematical and Physical Sciences Advisory Committee—*February 2008, p. 276*

Program Officers for Federal Funding Agencies—*October 2007, p. 1173 (DoD, DoE); December 2007, p. 1359 (NSF), December 2007, p. 1526 (NSF Mathematics Education)*

Program Officers for NSF Division of Mathematical Sciences—*November 2007, p. 1358*

Stipends for Study and Travel—*September 2007, p. 1022*

Undergraduates (REU) program sites. See http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf07569.

September 15, 2008: Nominations for Sloan Research Fellowships. See http://www.sloan.org/programs/fellowship_brochure.shtml or contact Sloan Research Fellowships, Alfred P. Sloan Foundation, 630 Fifth Avenue, Suite 2550, New York, NY 10111-0242.

September 19, 2008: Full proposals for NSF Focused Research Groups. See "Mathematics Opportunities" in this issue.

September 30, 2008: Nominations for 2008 Information-Based Complexity Young Researcher Award. See "Mathematics Opportunities" in this issue.

October 1, 2008: Applications for AWM Travel Grants. See http://www.awm-math.org/travelgrants.html; telephone: 703-934-0163; email: awm@awm-math.edu; or contact Association for Women in Mathematics, 11240 Waples Mill Road, Suite 200, Fairfax, VA 22030.

October 15, 2008: Applications for NSF Mathematical Sciences Postdoctoral Research Fellowships. See "Mathematics Opportunities" in this issue.

October 15, 2008: Proposals for NSA Mathematical Sciences Program research grants. See "Mathematics Opportunities" in this issue.

November 1, 2008: Applications for November review for the National Academies Postdoctoral and Senior Research Associateship Programs. See http://www7.nationalacademies.org/rap/index.html or contact Research Associateship Programs, National Research Council, Keck 568, 500 Fifth Street, NW, Washington, DC 20001; telephone 202-334-2760; fax 202-334-2759; email: rap@nas.edu.

November 15, 2008: Target date for receipt of applications for NSA Mathematics Sabbatical Program. See "Mathematics Opportunities" in this issue.

Contact Information for Mathematics Institutes

American Institute of Mathematics
360 Portage Avenue
Palo Alto, CA 94306-2244
Telephone: 650-845-2071
Fax: 650-845-2074
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http://www.aimath.org

Stefan Banach International Mathematical Center
8 Śniadeckich str., P.O. Box 21
00-956 Warszawa, Poland
Telephone: 48 (0) 22 522-82-32
Fax: 48 (0) 22 622-57-50
email: Banach.Center.Office@impan.gov.pl
http://www.impan.gov.pl/BC

Banff International Research Station
c/o PIMS Central Office
University of British Columbia
200-1933 West Mall
Vancouver, BC V6T 1Z2, Canada
Telephone: 604-822-1649
Fax: 604-822-0883
email: birs-director@birs.ca
http://www.birs.ca

Center for Discrete Mathematics and Theoretical Computer Science (DIMACS) CoRE Building, 4th Floor
Rutgers University
96 Frelinghuysen Road
Piscataway, NJ 08854-8018
Telephone: 732-445-5930
Fax: 732-445-5932
email: center-admin@dimacs.rutgers.edu
http://dimacs.rutgers.edu

Center for Scientific Computation and Mathematical Modeling (CSCAMM)
University of Maryland
Building #406, Paint Branch Drive
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email: cscamm@cscamm.umd.edu
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Department of Mathematical Sciences
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Fax: 91-44-2747-0225
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http://www.nim.nankai.edu.cn/nim_e/index.htm

Euler International Mathematical Institute
nab. Fontanki, 27
St. Petersburg 191023, Russia
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Fax: 7 812 310-53-77
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http://www.pdmi.ras.ru/EIMI/index.html

Fields Institute for Research in Mathematical Sciences
222 College Street, 2nd Floor
Toronto, Ontario M5T 3J1, Canada
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http://www.fields.utoronto.ca/

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http://www.ihp.jussieu.fr/

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Korea Institute for Advanced Study (KIAS)
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http://www.kias.re.kr

Mathematical Biosciences Institute
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Jennings Hall, 3rd Floor
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Statistical and Applied Mathematical Sciences Institute (SAMSI)
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email: contact@wias-berlin.de
http://www.wias-berlin.de/

Book List

The Book List highlights books that have mathematical themes and are aimed at a broad audience potentially including mathematicians, students, and the general public. When a book has been reviewed in the Notices*, a reference is given to the review. Generally the list will contain only books published within the last two years, though exceptions may be made in cases where current events (e.g., the death of a prominent mathematician, coverage of a certain piece of mathematics in the news) warrant drawing readers' attention to older books. Suggestions for books to include on the list may be sent to* notices-booklist@ams.org.

*Added to "Book List" since the list's last appearance.

Alfred Tarski: Life and Logic, by Anita Burdman Feferman and Solomon Feferman. Cambridge University Press, October 2004. ISBN 0-521-80240-7. (Reviewed September 2007.)

Amongst Mathematicians: Teaching and Learning Mathematics at University Level, by Elena Nardi. Springer, November 2007. ISBN-13: 978-0-387-37141-2.

The Archimedes Codex: How a Medieval Prayer Book Is Revealing the True Genius of Antiquity's Greatest Scientist, by Reviel Netz and William Noel. Da Capo Press, October 2007. ISBN-13: 978-0-3068-1580-5.

The Artist and the Mathematician: The Story of Nicolas Bourbaki, the Genius Mathematician Who Never Existed, by Amir D. Aczel. Thunder's Mouth Press, August 2006. ISBN 1-5602-5931-0. (Reviewed October 2007.)

Benjamin Franklin's Numbers: An Unsung Mathematical Odyssey, by Paul C. Pasles. Princeton University Press, October 2007. ISBN-13: 978-0-6911-2956-3.

Bourbaki, a Secret Society of Mathematicians, by Maurice Mashaal. AMS, June 2006. ISBN 0-8218-3967-5. (Reviewed October 2007.)

The Calculus Wars: Newton, Leibniz, and the Greatest Mathematical Clash of All Time, by Jason Socrates Bardi. Thunder's Mouth Press, April 2007. ISBN-13: 978-1-5602-5992-3.

A Certain Ambiguity: A Mathematical Novel, by Gaurav Suri and Hartosh Singh Bal. Princeton University Press, June 2007. ISBN-13: 978-0-6911-2709-5. (Reviewed February 2008.)

Descartes: A Biography, by Desmond Clarke. Cambridge University Press, March 2006. ISBN 0-521-82301-3. (Reviewed January 2008.)

Discovering Patterns in Mathematics and Poetry, by Marcia Birken and Anne C. Coon. Rodopi, February 2008. ISBN-13: 978-9-0420-2370-3.

Does Measurement Measure Up?: How Numbers Reveal and Conceal the Truth, by John Henshaw. Johns Hopkins University Press, March 2006. ISBN-13: 978-0-8018-8375-0.

Ernst Zermelo: An Approach to His Life and Work, by Heinz-Dieter Ebbinghaus. Springer, April 2007. ISBN-13: 978-3-540-49551-2.

**Euclidean and Non-Euclidean Geometries: Development and History*, fourth revised and expanded edition, by Marvin Jay Greenberg. W. H. Freeman, September 2007. ISBN-13: 978-0-7167-9948-1.

Flatland—The Movie: A Journey of Many Dimensions. Flatworld Productions, 2007. Special Educator Edition DVD, http://store.flatlandthemovie.com. (Reviewed November 2007.)

Fly Me to the Moon: An Insider's Guide to the New Science of Space Travel, by Edward Belbruno. Princeton University Press, January 2007. ISBN-13: 978-0-6911-2822-1. (Reviewed April 2008.)

The Great π/e Debate: Which Is the Better Number?, DVD by Colin Adams and Thomas Garrity. Mathematical Association of America, 2007. ISBN 0-88385-900-9.

Group Theory in the Bedroom, and Other Mathematical Diversions, by Brian Hayes. Hill and Wang, April 2008. ISBN-13: 978-0-8090-5219-6.

**Guesstimation: Solving the World's Problems on the Back of a Cocktail Napkin*, by Lawrence Weinstein and John A. Adam. Princeton University Press, April 2008. ISBN-13: 978-0-6911-2949-5.

A History of Abstract Algebra, by Israel Kleiner. Birkhäuser, October 2007. ISBN-13: 978-0-8176-4684-4.

How Mathematicians Think: Using Ambiguity, Contradiction, and Paradox to Create Mathematics, by William Byers. Princeton University Press, May 2007. ISBN-13: 978-0-6911-2738-5. (Reviewed December 2007.)

How Round Is Your Circle, by John Bryant and Chris Sangwin. Princeton University Press, January 2008. ISBN-13: 978-0-6911-3118-4.

**Impossible?: Surprising Solutions to Counterintuitive Conundrums*, by Julian Havil. Princeton University Press, April 2008. ISBN-13:978-0-6911-3131-3.

The Indian Clerk, by David Leavitt. Bloomsbury USA, September 2007. ISBN-13: 978-1-5969-1040-9.

An Introduction to Gödel's Theorems, by Peter Smith. Cambridge University Press, August 2007. ISBN-13: 978-0-521-67453-9.

Irreligion: A Mathematician Explains Why the Arguments for God Just Don't Add Up, by John Allen Paulos. Hill and Wang, December 2007. ISBN-13: 978-08090-5919-5. (Reviewed in this issue.)

Karl Pearson: The Scientific Life in a Statistical Age, by Theodore M. Porter. Princeton University Press, (new edition) December 2005. ISBN-

13: 978-0-6911-2635-7. (Reviewed December 2007.)

The Legacy of Mario Pieri in Geometry and Arithmetic, by Elena Anne Marchisotto and James T. Smith. Birkhäuser, May 2007. ISBN-13: 978-0-8176-3210-6.

Leonhard Euler, a Man to Be Reckoned With, by Andreas K. Heyne and Alice K. Heyne. Birkhäuser, 2007. ISBN-13: 978-3-7643-8332-9. (Reviewed March 2008.)

Making Mathematics Work with Needlework: Ten Papers and Ten Projects, edited by Sarah-Marie Belcastro and Carolyn Yackel. A K Peters, September 2007. ISBN-13: 978-1-5688-1331-8.

The Math behind the Music, by Leon Harkleroad. Cambridge University Press, August 2006. ISBN-13: 978-0-521-00935-5.

Math Doesn't Suck: How to Survive Middle-School Math without Losing Your Mind or Breaking a Nail, by Danica McKellar. Hudson Street Press, August 2007. ISBN-13: 978-1-5946-3039-2.

Mathematical Mind-Benders, by Peter Winkler. A K Peters, August 2007. ISBN-13: 978-1-5688-1336-3.

The Mathematician's Brain, by David Ruelle. Princeton University Press, July 2007. ISBN-13: 978-0-6911-2982-2.

Mathematics at Berkeley: A History, by Calvin C. Moore. A K Peters, February 2007. ISBN-13: 978-1-5688-1302-8.

Measuring the World, by Daniel Kehlmann. Pantheon, November 2006. ISBN 0-375-42446-6. (Reviewed June/July 2008.)

The Millennium Prize Problems, edited by James Carlson, Arthur Jaffe, and Andrew Wiles. AMS, June 2006. ISBN-13: 978-0-8218-3679-8.

The Mind of the Mathematician, by Michael Fitzgerald and Ioan James. Johns Hopkins University Press, May 2007. ISBN-13: 978-0-8018-8587-7.

More Mathematical Astronomy Morsels, by Jean Meeus. Willmann-Bell, 2002. ISBN 0-943396743.

More Sex Is Safer Sex: The Unconventional Wisdom of Economics, by Steven E. Landsburg. Free Press, April 2007. ISBN-13: 978-1-416-53221-7. (Reviewed June/July 2008.)

Mr. Hopkins' Men: Cambridge Reform and British Mathematics in the 19th Century, by Alex D. D. Craik. Springer, February 2007. ISBN-13: 978-1-8480-0132-9.

Music and Probability, by David Temperley. MIT Press, January 2007. ISBN-13: 978-0-2622-0166-7.

Music: A Mathematical Offering, by David J. Benson. Cambridge University Press, December 2006. ISBN-13: 978-0-521-61999-8.

New Theories of Everything, by John D. Barrow. Oxford University Press, July 2007. ISBN-13: 978-0-192-80721-2.

Number Story: From Counting to Cryptography, by Peter M. Higgins. Springer, February 2008. ISBN-13: 978-1-8480-0000-1

The Numbers behind NUMB3RS: Solving Crime with Mathematics, by Keith Devlin and Gary Lorden. Plume, August 2007. ISBN-13: 978-0-4522-8857-7.

Perfect Figures: The Lore of Numbers and How We Learned to Count, by Bunny Crumpacker. Thomas Dunne Books, August 2007. ISBN-13: 978-0-3123-6005-4.

The Poincaré Conjecture: In Search of the Shape of the Universe, by Donal O'Shea. Walker, March 2007. ISBN-13: 978-0-8027-1532-6. (Reviewed January 2008.)

Poincaré's Prize: The Hundred-Year Quest to Solve One of Math's Greatest Puzzles, by George Szpiro. Dutton Adult, June 2007. ISBN-13: 978-0-525-95024-0. (Reviewed January 2008.)

The Presidential Election Game, by Steven J. Brams. A K Peters, December 2007. ISBN-13: 978-1-5688-1348-6.

The Probability of God: A Simple Calculation That Proves the Ultimate Truth, by Stephen D. Unwin. Three Rivers Press (October 26, 2004). ISBN-13: 978-1-4000-5478-7. (Reviewed February 2008.)

**Pursuit of Genius: Flexner, Einstein, and the Early Faculty at the Institute for Advanced Study*, by Steve Batterson. A K Peters, June 2006. ISBN 1-5688-1259-0. (Reviewed in this issue.)

The Pythagorean Theorem: A 4000-Year History, by Eli Maor. Princeton University Press, May 2007. ISBN-13: 978-0-6911-2526-8.

Random Curves: Journeys of a Mathematician, by Neal Koblitz. Springer, December 2007. ISBN-13: 978-3-5407-4077-3.

Super Crunchers: Why Thinking-by-Numbers Is the New Way to Be Smart, by Ian Ayres. Bantam, August 2007. ISBN-13: 978-0-5538-0540-6.

Superior Beings: If They Exist, How Would We Know? Game-Theoretic Implications of Omnipotence, Omniscience, Immortality, and Incomprehensibility, by Steven Brams. Springer, second edition, November 2007. ISBN-13: 978-0-387-48065-7. (Reviewed February 2008.)

The Symmetries of Things, by John H. Conway, Heidi Burgiel, and Chaim Goodman-Strauss. A K Peters, May 2008. ISBN-13: 978-1-5688-1220-5.

Symmetry: A Journey into the Patterns of Nature, by Marcus du Sautoy. Harper, March 2008. ISBN-13: 978-0-0607-8940-4.

Thinking about Gödel and Turing: Essays on Complexity, 1970–2007, by Gregory J. Chaitin. World Scientific, August 2007. ISBN-13: 978-9-8127-0895-3.

The Triumph of Numbers: How Counting Shaped Modern Life, by I. B. Cohen. W. W. Norton, July 2006. ISBN-13: 978-0-393-32870-7. (Reviewed December 2007.)

The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next, by Lee Smolin. Joseph Henry Press, October 2006. ISBN 0-309-10192-1. (Reviewed September 2007.)

Unknown Quantity: A Real and Imaginary History of Algebra, by John Derbyshire. Joseph Henry Press, May 2006. ISBN 0-309-09657-X. (Reviewed May 2008.)

Useless Arithmetic: Why Environmental Scientists Can't Predict the Future, by Orrin Pilkey and Linda Pilkey-Jarvis. Columbia University Press, February 2007. ISBN 0-231-13212-3. (Reviewed April 2008.)

The Volterra Chronicles: The Life and Times of an Extraordinary Mathematician, by Judith R. Goodstein. AMS, February 2007. ISBN-13: 978-0-8218-3969-0. (Reviewed March 2008.)

**The Wraparound Universe*, by Jean-Pierre Luminet. A K Peters, March 2008. ISBN-13: 978-1-5688-1309-7.

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From the AMS Secretary

Report of the Executive Director, State of the AMS, 2008

When I report to the Council each spring, I try to look at the AMS from a different perspective—membership, programs, meetings, or publishing. This year, I will look at the AMS from yet another perspective—its history. Because the Society celebrates its 120th anniversary in 2008, I want to look at the Society over time and contrast what we do now with what we have done in the past. That's a big job, with only a small amount of time to accomplish it. This will therefore be a condensed history, designed more to highlight how we have changed rather than to provide a comprehensive history. If you are interested in finding out more, there are excellent resources online at

Volume I: A Semicentennial History of the American Mathematical Society, 1888—1938
`http://www.ams.org/online_bks/hmreprint/`

Volume I: A History of the Second Fifty Years, American Mathematical Society, 1939 – 1988
`http://www.ams.org/online_bks/hmpitcher/`

AMS History of Mathematics, Volume 1: A Century of Mathematics in America, Part I
`http://www.ams.org/online_bks//hmath1/`

Overview

The American Mathematical Society was founded by graduate students. In the spring of 1887, while he was in his second year as a graduate student at Columbia University, Thomas Fiske was told by one of his professors to spend some time at Cambridge University in England. He went later that year and immersed himself in mathematics. Even more than his lectures, however, he found the regular meetings of the London Mathematical Society exciting. He went with J. W. L. Glaisher, "who spent with me many evenings in heart to heart conversations … and who entertained me with gossip about scores of contemporary and earlier mathematicians." Fiske later wrote: "On my return to New York I was filled with the thought that there should be a stronger feeling of comradeship among those interested in mathematics, and I proposed to my classmates … that we should try to organize a local mathematical society."

Thomas Fiske

They succeeded, and the New York Mathematical Society was formed in 1888. It grew slowly at first (by the end of 1889 it had only sixteen members), but the members held regular meetings and soon began to publish a *Bulletin*. In 1894, when it was clear that the organization was truly national in scope, the name was changed to the American Mathematical Society and the organization held its first summer meeting (in conjunction with the American Association for the Advancement of Science).

For the next thirty years, the AMS continued to grow along with American mathematics. At the turn of the century, most prominent mathematicians in America were educated in Europe. Research mathematics was not a tradition in American universities, and mathematics was often associated with more practical matters. (The second president of the Society was an actuary; the third president an astronomer.) As the new century dawned, that tradition began to change. American trained mathematicians became more visible (E. H. Moore among them) and research became more important. Birkhoff's proof of Poincaré's "last geometric theorem" greatly enhanced the reputation of American mathematics, and American mathematicians began to play a role in the international community. The Society continued to grow, expanding its

meetings and adding the *Transactions* and the Colloquium series to its publications.

Until 1923, the Council was the only governing body of the AMS. In that year, the AMS was incorporated (in the District of Columbia) and the Board of Trustees was added to look after the financial affairs of the Society. The Society headed into a quarter-century of steady operations—regular meetings, the *Bulletin* and *Transactions*, an occasional book. The depression took its toll on the AMS (revenues were flat for the decade of the 1930s) and not much changed until the war. Then, everything changed. Mathematics became important, disputes broke out between pure and applied mathematicians, and in the aftermath of the war, people recognized that science and mathematics played a new role in the country's future. There was much acrimony about pure versus applied, both during the war and afterwards. This was the time when the Society for Industrial and Applied Mathematics was formed, along with applied mathematics departments at several universities. It was a dark period for mathematics that affected attitudes for decades afterwards, and many of the wounds are still healing.

ENIAC (circa 1948).

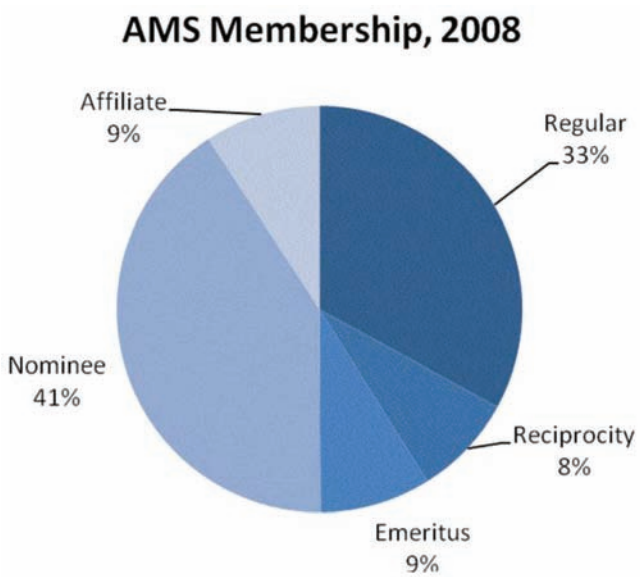
By the late 1940s, the Society had grown more complex. For its first sixty years, the secretary ran most operations of the AMS (with the treasurer and, to a lesser extent, the president). But as the budget and staff began to grow, it became clear that someone was needed to run the business. The position of executive director was created in 1949. Around this time, the Society was also forced to move its offices from New York (Columbia University), where it had been since its beginning, and it chose Providence as its new home. (Providence was the location of *Mathematical Reviews*, which now was a key part of the AMS. Its founder, Otto Neugebauer, was a faculty member at Brown University.)

During the remainder of the twentieth century, the AMS grew. It went from a staff of about ten to 215 (peaking near 250); its annual budget went from US$145,000 to US$25,000,000; and it expanded nearly everything it did—membership, meetings, outreach, education, and publications—slowly, over its second sixty years. The Society became a leading force internationally, organizing two international congresses (1950 and 1986) and reaching out to other mathematics societies around the world. It became more politically engaged (although not always in the most productive way). It promoted and developed tools ($\mathcal{A}_{\mathcal{M}}\mathcal{S}$-TEX, AMS-fonts, and various packages) for writing mathematics in the new world of computers. It involved itself in professional issues, from employment to research funding. The AMS evolved over the second half of its life, in some ways returning to its roots.

Membership

In 2008, the AMS will have a little over 32,000 members. That overall figure is misleading, however, because there are many different categories of membership. Regular members are divided into three categories (high, low, and entry). There are more and more life and emeritus members each year. Reciprocity members (who belong to a reciprocating society and pay half-dues) make up a significant group from outside North America; so do affiliate members (from developing countries). The largest category of members is "nominee/student", which now makes up about 40% of the membership. About a third of our members are from outside North America.

We also have over 500 institutional members of the AMS. These institutions pay dues that vary with their size, and in return receive certain benefits, which include discounts on publications (often exceeding the dues) as



well as certain rights to appoint those nominee members mentioned above.

Membership wasn't always so varied. From the sixteen members in its first year, the AMS had grown only to 251 when it changed its name in 1894. It took until 1921 to exceed 1,000 members; until 1937 to exceed 2,000. For much of this time (1891–1921) the dues level was set at a steady US$5, and membership was essentially undifferentiated with just a single category. Then, in the next two decades, dues began to rise and membership became more complicated. The AMS added reciprocity members (beginning with our parent, the London Mathematical Society) and life memberships were created. By 1937, dues had risen to US$9, and while the number of reciprocity members was small (52), it was clearly growing. Institutional memberships were created around this time as well.

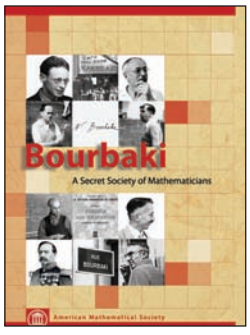
The classes of membership remained relatively stable until the early 1970s, when the Council created "nominee" members as a way to entice young mathematicians to join the AMS early in their careers. Affiliate members (they were originally called "Category-S") were added in the early 1980s.

One chapter in the Society's attempts to deal with membership might better be forgotten. In 1965, the minutes of the Executive Committee and Board of Trustees record the following action:

> The establishment of US$28 as membership dues for a husband–wife joint memberships [sic]. The husband is to be billed at the rate of US$28 for dues and will receive the *Notices* and the *Bulletin* as a privilege of membership. The wife will pay no dues but will be allowed a choice of subscriptions at members' rates, and both will be accorded all other privileges of membership.

The AMS still offers family memberships, but they are not described in such language—a stark reminder of attitudes in 1965.

While the records are incomplete, it seems that membership in the Society was only denied to one mathematician, Nicolas Bourbaki. He had applied for reciprocity membership in 1948, having recently joined the Société Mathématique de France. The secretary of the AMS, J. R. Kline, rejected the application, saying that "That Society has two types of membership, individual and institutional, and Bourbaki comes under neither classification." The matter eventually made its way to the Council in December 1950, and the Council pronounced that (1) Bourbaki was not eligible for reciprocity membership, (2) Bourbaki was eligible for institutional membership, and (3) the constituents of Bourbaki could individually become members. A reply came from J. Dieudonné soon after: "If the French Mathematical Society took itself as seriously as seems to be the case with the AMS, this letter and the breach of the reciprocity agreement implied therein could seriously jeopardize the good relations between the two Societies." The Council did not back down.



Meetings

Meetings have always been an essential part of the Society. Each year, we hold the Joint Mathematics Meeting with the Mathematical Association of America. In recent years, a number of other organizations have participated in the meeting as well. This past meeting in San Diego set a record for attendance—about 5,500 people. Each year, the joint meeting seems to grow and become richer and more complex. We also hold eight regional meetings each year, four in the spring and four in the fall, and those meetings continue to grow as well.

The AMS holds joint meetings with the *Sociedad Matemática Mexicana* on a regular basis, and the last one in May 2007 took place in Zacatecas, Mexico. In addition to these, the AMS has approximately one joint international meeting each year, organized jointly with one or more societies in another country. During 2007 we held two such meetings—one in Warsaw, Poland, and another in New Zealand. During 2008 we will hold two more—one in Rio de Janeiro, Brazil, and the other in Shanghai, China. Such meetings provide opportunities for mathematicians to make international connections, but they also provide a way for the societies to connect as well.

In a sense, the AMS was built on meetings. Thomas Fiske set out to create a mechanism to hold regular meetings, and for the first few years of the Society that was essentially all it did. Many other parts of the Society grew from meetings—the *Bulletin* as a way to publicize presentations, the Colloquium series as a way to publish the Colloquium lectures, the Gibbs lectures as a way to reach out to the public.

For many years, the annual meeting was held between Christmas and New Year's. It consisted of a few hour-talks mixed with many short presentations (contributed papers). Over time, the number of hour- talks has increased, and the notion of "special sessions" has become a staple of all our meetings. In 1963, there were five special sessions; today, there are more than thirty at the Joint Meeting, and dozens more at our other meetings.

Summer meetings were a part of the AMS program until

A Sample of Gibbs Lectures (mid-century)

- Albert Einstein, 1934
- Vannevar Bush, 1935
- Theodore von Kármán, 1939
- Harry Bateman, 1943
- John von Neumann, 1944
- S. Chandrasekhar, 1946
- Hermann Weyl, 1948
- Norbert Wiener, 1949
- G. E. Uhlenbeck, 1950
- Kurt Gödel, 1951
- Marston Morse, 1952
- Wassily Leontief, 1953
- K. O. Friedrichs, 1954
- M. H. Stone, 1956

1996. They were usually smaller, but often attracted families, who combined the meeting with a vacation. The Colloquium lectures were given at the summer meeting each year. Gradually, however, summer meetings seemed to have less and less interest for AMS members, and eventually they were discontinued.

Regional meetings have evolved over many years. When they started, these meetings were invariably held in New York or Chicago—a way to supplement the larger meetings with smaller meetings that focused on a more limited set of topics. There were usually seven or fewer each year. Over the past fifty years, these meetings have become more regular and organized, with two held in each of the four regions, one in spring and one in fall.

For many years, the summer and winter joint meetings with the MAA were five-day meetings, with six half days assigned to the AMS and four half days to the MAA. The two days in the middle were interlaced. In 1984 the format was changed to a four-day meeting with all sessions intermingled. These joint meetings have become far more complex in recent years, both because the AMS and MAA have added many more activities (talks, panels, social events) and because a number of other organizations have joined the meeting as well. The governance of the joint meeting is still done by the two primary organizations, AMS and MAA. As the meetings have grown, we have had to accommodate the need for more space. Because meetings have to be planned many years in advance (we are currently working on 2016) this is not always easy to do.

Future Joint Meetings

Washington, DC	2009
San Francisco	2010
New Orleans	2011
Boston	2012
San Diego	2013
Baltimore	2014
San Antonio	2015

Programs/Outreach

In a certain sense, this is the part of the AMS for which there is no good historical perspective. For its first sixty years, the AMS concentrated on meetings and, to a lesser extent, on publications. That's not surprising; the Society had only a handful of staff, and it was largely volunteer run with only modest resources. In its second sixty years, this all changed.

Here is a partial list of some of the programs the AMS runs today.

• The **annual survey**, which covers more than 1,500 mathematics departments and reports on employment, salaries, and demographic data.

• The **CBMS survey**, which takes place every five years and produces a comprehensive view of all aspects of mathematics in colleges and universities.[1]

• Production of **Assistantships and Graduate Fellowships**, which contains comprehensive information on graduate programs throughout the mathematical sciences.

• Production of **Employment Information in the Mathematical Sciences (EIMS)**, which is the standard location for advertising jobs.

• The **Employment Center**, which has evolved over the years from the old employment register. It now provides a convenient mechanism for employers and potential employees to meet at the annual meeting.

MathJobs.Org

• The support of **MathJobs**, which is a service that grows each year and makes the job application process easier for all those involved.[2]

• The **Young Scholars Program** that makes awards to summer programs for talented high school students. This year, this program has awarded US$100,000 in grants to help these programs. The AMS has been working to endow the program by raising US$2M for an endowment, and we are approaching that goal.

• The **Math in Moscow** Semester for Undergraduates, which supports visits of American undergraduates to the Independent University of Moscow for an intensive mathematical program, and is designed for the very best students.[3]

• **Early Careers** is an effort to answer the question, "What good is a mathematics degree?" It publishes profiles of undergraduate majors and encourages mathematics departments to collect such information.

• The **Society for the Advancement of Chicanos and Native Americans in Science (SACNAS)** has an annual meeting that brings together some spectacular students. The AMS has been an enthusiastic participant each year and provides financial support for part of this meeting.

• The **Ky Fan China Exchange Program** funds visits by distinguished North American mathematicians to Chinese departments, as well as visits by prominent young Chinese mathematicians to North American universities.

• The **Book and Journal Donation Program** helps mathematics to donate material to mathematics departments in developing countries, first by matching donors with recipients and then by paying for shipping costs.[4]

The newest program of the Society is **Mathematics Research Communities (MRC)**, which will begin in summer 2008. The goal is to bring together groups of young mathematicians in a common field, so that they make connections and possibly work cooperatively in the future. They will come together in groups of twenty or so, along with more senior mentors, for a week-long

[1] *The CBMS survey is carried out under the auspices of the Conference Board on the Mathematical Sciences and is funded by the National Science Foundation.*

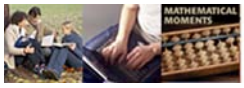
[2] *MathJobs is a cooperative effort of the AMS and the Mathematics Department at Duke University.*

[3] *Math in Moscow is supported by a grant from the National Science Foundation.*

[4] *The Book and Journal Donation Program is funded by donations from Stroock Family Foundation, supplemented by the Society's operating funds when necessary.*

conference (at Snow Bird, Utah), and then reconnect at a special session at the Joint Meeting. There will be additional opportunities to work together online. Part of the project is also to carry out longitudinal studies of their progress over a number of years, so that we can understand better the career path of young mathematicians. The project is funded by a grant from the National Science Foundation and will last for at least three years, and we hope far beyond that.

In 2000 the AMS created a public awareness office, which has grown steadily each year since and now carries out a set of regular activities that have made mathematical



Public Awareness

research more visible and better understood. **Mathematical Moments**, **Math in the Media**, and the **Feature Column** are all expository efforts, each aimed at a slightly different audience. Math Moments hang in classrooms around the country, and some of them have been translated into six different languages. **Headlines and Deadlines** helps to keep AMS members informed; **Who Wants to be a Mathematician** entertains and encourages high school students; **What's Happening** is a series of books aimed at exposing the mathematically interested population to recent mathematics. The public awareness office has connected mathematics to the new media in a way it never was before.

For nearly a decade in the 1980s, the Society talked about establishing an AMS **Washington Office** in order to advocate for mathematics. Finally, in 1993, the Society created the office, which has been headed by Sam Rankin since 1995. Its mission and operations have evolved over the past dozen years, and it now carries out many events each year, including annual **Science Policy Forums**, **Congressional briefings**, and **workshops of department chairs**. The Washington office also manages our **Congressional fellows** and **mass media fellows**.[5]

The main function of the Washington office is something that wasn't on the top of anyone's list before 1993. It gives mathematicians a presence in Washington, along with all the other organizations that advocate for science and research. When people gather to talk about mathematics, or when reporters ask for comments about science, mathematicians are included with physicists, chemists, biologists, and engineers. Sam Rankin who heads the Washington office chairs the Coalition for National Science Funding, which advocates for the National Science Foundation on behalf of many science and engineering societies. That makes mathematics part of mainstream science, and that has changed the general attitude about the importance of mathematics.

CNSF
COALITION FOR NATIONAL SCIENCE FUNDING

Many people think of prizes as an essential part of AMS activities, but it is somewhat surprising that they were largely absent from its first sixty years. The Bôcher Prize was first given in 1923 to honor AMS president Maxime Bôcher (1909–10). The two Cole Prizes, in algebra and number theory, were first given in 1928 and 1931. But there were no other prizes until a spate of new prizes appeared—the Veblen Prize (1964), the Birkhoff Prize (1968), and the Steele Prizes[6] (1970). Many more prizes have been created in recent years, and the Society now has a rich program of prizes and awards, both for research and for other activities (including outstanding departments and programs).

Surveys, employment services, programs for high school students, outreach to the developing world, public awareness, advocacy, and prizes—almost none of these was part of the Society's mission in its first sixty years (and few could have been carried out with only a few staff and a tiny budget).They have come to define the Society in its second sixty years, and they play an increasingly important role in all our activities.

Education

Education has always been problematic for the AMS. When the Society began in 1888, its purpose was clearly stated by its founders—preserving, supplementing, and utilizing the results of their mathematical studies so that "original investigations to which members may be led shall be brought before the society at its meetings." The AMS was focused on research. Indeed, Thomas Fiske wrote about teaching in an article he published in the 1905 *Bulletin*:

> Notwithstanding the great progress recently made in America by our science, we are far from being in a position that we can regard as entirely satisfactory.... the most pressing demand seems to be that those engaged in lecturing...at American universities should be given greater opportunities for private study and research. At present, the time of almost every university professor is taken up to a very large extent with...the care of comparatively young students. [*Bulletin*, February 1905, p. 245]

This would be a familiar theme over the next century: Less time teaching, more time for research.

But then as now, research mathematicians were often engaged in teaching, and from its earliest days the Society's members were mainly teachers. One of its greatest presidents, E. H. Moore (1901–02), was passionate about teaching. His retiring presidential address focused on education, and it contained this plea:

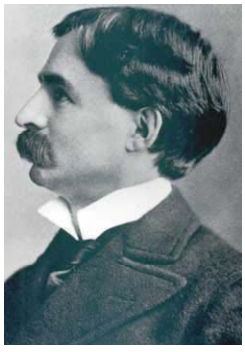
> The American Mathematical Society has, naturally, interested itself chiefly in promoting the

[5] *The Congressional fellow and mass media fellow programs are run through the American Association for the Advancement of Science, but fully supported by the AMS.*

[6] *These prizes were established in 1970 in honor of George David Birkhoff, William Fogg Osgood, and William Caspar Graustein, and are endowed under the terms of a bequest from Leroy P. Steele.*

> interests of research in mathematics. It has, however, recognized that those interests are closely bound up with the interests of education in mathematics. …Do you not feel with me that the AMS, as the organic representative of the highest interests of mathematics in this country, should be directly related with the movement of reform?…[*Bulletin*, May 1903, p. 412]

It was a plea that went largely unheeded by most of the Society's leadership. Indeed, twelve years later, when the *American Mathematical Monthly* came to AMS for help, the AMS dismissed Moore's words. The *Monthly* had become the premier journal for college teachers, but it was in financial trouble and needed an institutional home. They hoped that the Society would provide it and, in doing so, would take on the responsibility for collegiate teaching. The issue was hotly debated, a committee was formed to study the problem (plus ça change…), and by a narrow vote of 3-2 the AMS turned down the *Monthly*. Soon after, the Mathematical Association of America was formed to provide a home for the *Monthly*, and it became the organization devoted to collegiate mathematics teaching.



E. H. Moore

That decision more than ninety years ago shaped the course of the AMS for most of the twentieth century. For decades afterwards, the AMS scarcely dealt with education at all. Education was the business of the MAA. Even in the turbulent times of the "new math", the AMS stayed (mainly) on the sidelines. But, in the last two decades of the twentieth century, the AMS began slowly to renew its interest in education and began to reinsert itself in areas it had previously avoided. The Committee on Education became active in the 1990s, and it now holds an annual forum in Washington that attracts dozens of department chairs and their representatives. Each year the AMS provides judges and prizes for mathematics at the Intel Science Fair[7]; it provides eight US$3,000 scholarships to undergraduate mathematics majors[8]; and it has enthusiastically supported Research Experiences for Undergraduate programs with two separate conferences in the past ten years to help those running these programs to share information.[9]

Most recently, the AMS has been engaged in two other projects, one aimed at providing resources for high school students (and their teachers) so they can prepare themselves for serious undergraduate work in mathematics.

[7] *The Intel Science Fair activity is partially supported by the Menger Prize endowment, given in honor of Karl Menger.*

[8] *The scholarships are funded by the Trjitzinsky Fund, given in honor of Waldemar Trjitzinsky.*

[9] *Both conferences are supported by grants from the National Security Agency.*

A Sample of Colloquium Lectures (first 50 years)

1896, **Maxime Bôcher**, *Linear differential equations and their applications.*

1906, **Eliakim H. Moore**, *On the theory of bilinear functional operations.*

1913, **Leonard E. Dickson**, *On invariants and the theory of numbers.*

1913, **William F. Osgood**, *Topics in the theory of functions of several complex variables.*

1916, **Oswald Veblen**, *Analysis situs.*

1920, **G. D. Birkhoff**, *Dynamical systems.*

1927, **E. T. (Eric Temple) Bell**, *Algebraic arithmetic.*

1927, **Anna J. Pell Wheeler**, *The theory of quadratic forms in infinitely many variables and applications.*

1929, **R. L. (Robert Lee) Moore**, *Foundations of point set theory.*

1930, **Solomon Lefschetz**, *Topology.*

1931, **Marston Morse**, *The calculus of variations in the large.*

1932, **Joseph F. Ritt**, *Differential equations from the algebraic standpoint.*

1935, **Harry S. Vandiver**, *Fermat's last theorem and related topics in number theory.*

1937, **John von Neumann**, *Continuous geometry.*

The other project focuses on the first year of college mathematics and seeks ways to make a difference by changing the way mathematics departments deal with first year instruction. That effort is now moving into a new phase, which we hope will offer truly practical solutions.

All this interest in education, from K–12 to graduate level, is starkly different from the attitude expressed by the AMS in 1915 when it turned down the *Monthly*. The AMS now finds itself keenly interested in all aspects of education—more involved with the MAA, with which we share a common interest in promoting *both* quality research *and* quality education. That broader interest is good for the future of mathematics.

Publishing

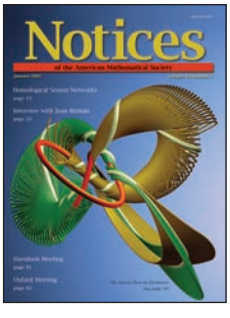
Membership, meetings, programs, public awareness, advocacy, and education—all of these have come to be essential aspects of the Society's personality. But most of this would be impossible if the AMS had not nurtured and eventually expanded its publishing program. Indeed, AMS publishing is what makes the Society different. It's the reason the AMS has more than 200 employees (we own our own printing plant and warehouse), and it's certainly the reason the AMS has a budget of US$25M.

We now publish a dozen journals with more than 20,000 pages annually. We publish more than 100 new books each year as well, and we keep more than 3,000 titles in print—an extraordinary number for any publisher. And, of

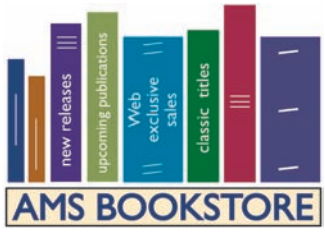
course, we publish the Math Reviews database, in several formats but most especially as MathSciNet online.

We make money from our publishing, of course, and that's what allows us to do all those other things. But we publish for many other reasons, which include competing with other publishers (to keep them honest), providing mathematicians a friendly venue for their work, and disseminating research material that might otherwise never be seen by the broad community. The competition has been especially important for journals, but it plays an ever larger role in our book publishing as well.

The AMS has always viewed publishing, along with meetings, as an integral part of its activities. Soon after its founding, the *Bulletin* was created as a vehicle for publicizing what happened at meetings. The *Transactions* was started in 1900 in order to give American mathematicians a more amenable outlet for their research. (European journals seemed to be somewhat snobbish towards the fledgling American mathematics community.) The *Proceedings* cleaved itself from the *Bulletin* in 1950 as the "gray issues", replacing many small research papers that were previously published in the primary member journal. The *Memoirs* were created at about the same time, publishing papers at the other end of the spectrum (long!) in a series that was part book, part journal. *Mathematics of Computation* grew from World War II as *Mathematical Tables and Other Aids to Computation*. It was originally published by the National Research Council, but the AMS took over publishing (but not editorial control) in 1961. By 1966, the journal had been fully transferred to the AMS. The *Journal of the AMS* is the youngest of the four primary journals, which after a ten-year debate first appeared in 1988. It has been a remarkable success in every way, and now is considered among the top few mathematics journals in the world. The *Notices* was redesigned and first appeared in its new (enhanced) format in 1995. All the other journals, including our translation journals, were acquired over time in a variety of ways.



The *Notices* and the *Bulletin* are now the two "member" journals of the AMS, and printed copies are mailed to all members.[10] Both are "open access"—that is, they are freely available online to all members and non-members alike, and people have sometimes wondered why we give away our most important member benefit. But making *member* journals available to the world makes them *more* valuable, not less, and because mathematicians everywhere can access these journals, they provide an easy way to reach all mathematicians. In this sense, the *Bulletin* and *Notices* are a donation, from AMS members to the community of mathematicians.



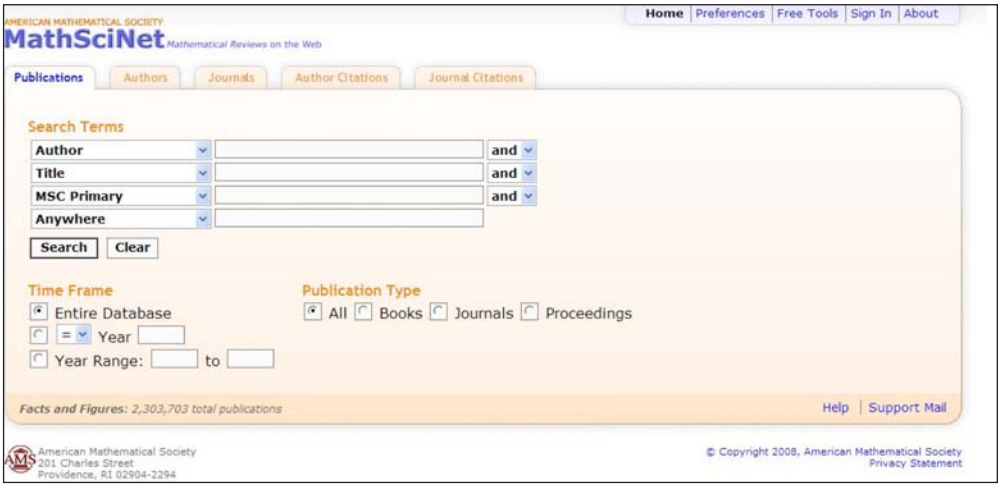
Books have developed more slowly than journals. The oldest series, *Colloquium*, began as a way to publish the proceedings of colloquia given at the annual meeting. The series originated in the earliest days of the Society with the Chicago Congress and Evanston Colloquium of 1893 (not an AMS meeting, but an opportunity nonetheless) and it continued to publish lectures as the colloquium lectures became ever more popular. For its first fifty years, the Society kept largely to this format and style. Then in 1940 the AMS published *Mathematical Surveys* (using a commercial publisher to do the production) and soon after published proceedings of various kinds. In the next fifty years, the AMS was a "small" publisher of books—conference proceedings, volumes from summer workshops, an occasional Survey, and regular translations, especially from Russian. In 1988 the Society published just over thirty new titles—its specialty consisted of books in which commercial publishers had little interest.

Around the time of its centennial, the AMS set out to reinvigorate and expand its book program. In the past twenty years, it has added series (*Graduate Studies*, *Student Math Library*) and increased every part of the program from acquisitions to marketing. Book publishing is a complicated business, however, and it grows over decades, not months. It has taken these twenty years to expand the program to its present state, and it is poised to expand much further in the future.

Mathematical Reviews is in many ways the most important single publication of the Society. When it was started by Otto Neugebauer in 1940, it was a relatively small operation, patterned on *Zentralblatt*, for which Neugebauer had been editor. (When *Zentralblatt* fell under the influence of the Nazi regime, Neugebauer had fled to the United States.) Math Reviews was run from an office at Brown

Kevin Clancey, MR executive editor (left) and Bernd Wegner, *Zentralblatt* editor-in-chief.

[10] *Affiliate members must choose between the two journals.*



University using a staff of four people. In its first year of operation (1940), it had 350 reviewers and published 400 pages containing 2,120 reviews.

Math Reviews grew year by year, and by the 1970s it consisted of those giant orange volumes that one pored over in libraries, trying to find just the right reference in what often took hours. Through remarkable foresight, the Society began to computerize the data long before anyone had thought about a worldwide web. When the Web came into being, the AMS created an interface for that database, and MathSciNet was born in 1996. The online version of Math Reviews goes through an annual revision each year, with a new version appearing each September, and MathSciNet has become an indispensible tool for mathematicians around the world. To the original data, we have added links to original articles (nearly a million of them), links to retro-digitized material that has recently appeared, vast amounts of citation data (over three million citations), and many other tools that can be used to carry out searches in seconds, where hours were previously required. Math Reviews now adds over 80,000 items each year, using more than 12,000 reviewers and a staff of over seventy people located in Ann Arbor. The database has more than 2.3 million items written by almost half a million authors and published in over 1,800 journals. Math Reviews has grown up.

One feature of Math Reviews relies on sixty-eight years of effort, which at one time may have seemed frivolous: For its entire existence, the staff at Math Reviews has identified each author of each article, sometimes doing detective work that might even require making phone calls. As a consequence, the database has a unique identifier for each author, and one can do many things (for example, call up all papers by a particular author) that would be hard to do without author identification. This has become ever more important in an electronic age, when tools such as Google return tens of thousands of results and find it particularly hard to differentiate between many people with the same name.

The Future

Looking back over the history of the AMS, it's hard to miss the irony: The AMS was founded by graduate students who wanted to communicate the excitement and vitality of mathematics to one another; 120 years later, we are creating programs to communicate the excitement and vitality of mathematics to graduate students. To be sure, the Society has done many valuable things in the intervening years—meetings, publications, programs, service, awareness, and advocacy—and it has done all those things remarkably well. All these things partly accomplished the original purpose of the Society. But in the past, the AMS sometimes viewed its mission far too narrowly and circumscribed mathematical research not only from the rest of science, but from other parts of mathematics.

The Society has matured in the past few decades—embraced a broader vision of mathematics, accepted its responsibility for education, and taken on a larger role for itself as a society. Much of what the AMS did for a century laid the foundation for these changes, and perhaps it was good to grow in this way, slowly over time.

But it's also good to come back to our roots.

—John Ewing
Executive Director

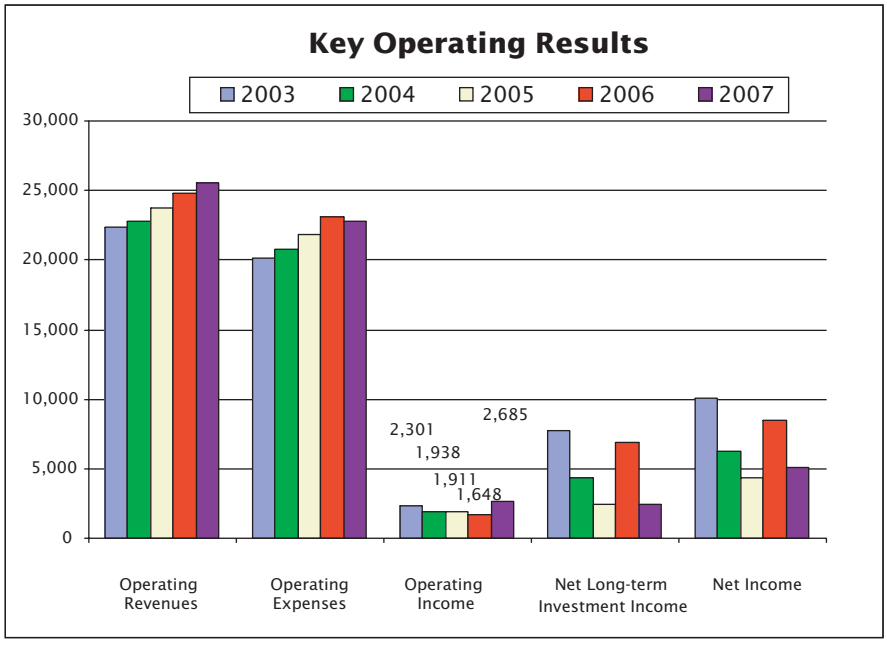
Report of the Treasurer (2007)

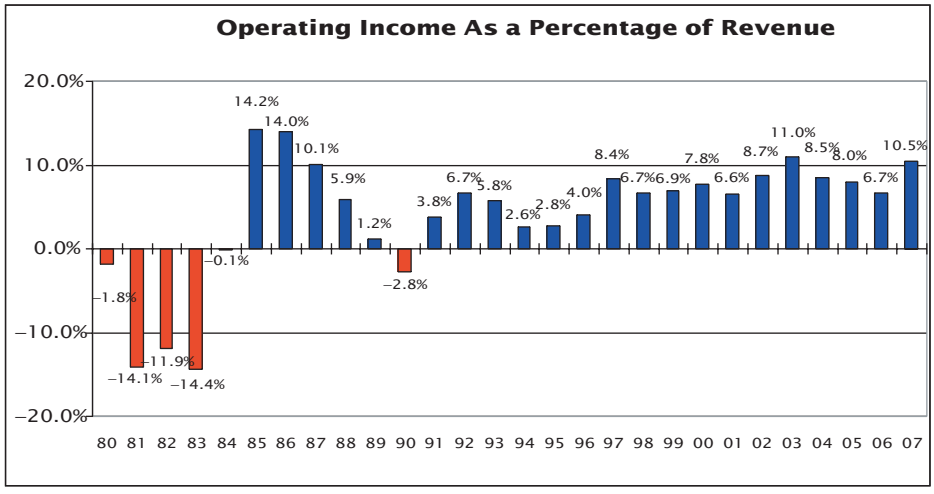
I. Introduction

One of the most important duties of the treasurer is to lead the Board of Trustees in the oversight of financial activities of the Society. This is done through close contact with the executive staff of the Society, review of internally generated financial reports, review of audited financial statements, and direct contact with the Society's independent auditors. Through these and other means, the Trustees gain an understanding of the finances of the Society and the important issues surrounding its financial reporting. The Report of the Treasurer is presented annually and discusses the financial condition of the Society as of the immediately preceding fiscal year end, and the results of its operations for the year then ended. It contains summary information regarding the operating results and financial condition of the Society for 2007, a review of 2007 operations, containing more detailed information regarding the Society's operations, and a discussion of the assets and liabilities of the Society. Finally, in the last part of the Report, there are financial statements derived principally from the Society's audited financial statements, which present the balance sheet, statement of activities (akin to an income statement in a for-profit organization), and information regarding the Society's invested funds.

Editor's note: All dollar figures are given in USDollars.

The Society segregates its net assets, and the activities that increase or decrease net assets, into three types. Unrestricted net assets are those that have no requirements as to their use placed on them by donors outside the Society. A substantial majority of the Society's net assets and activities are in this category. Temporarily restricted net assets are those with donor-imposed restrictions or conditions that will lapse upon the passage of time or the accomplishment of a specified purpose. Examples of the Society's temporarily restricted net assets and related activities include grant awards and the spendable income from prize and other income-restricted endowment funds. Permanently restricted net assets are those that must be invested in perpetuity and are commonly referred to as endowment funds. The accompanying financial information principally relates to the unrestricted net assets, as this category includes the operating activities of the Society.

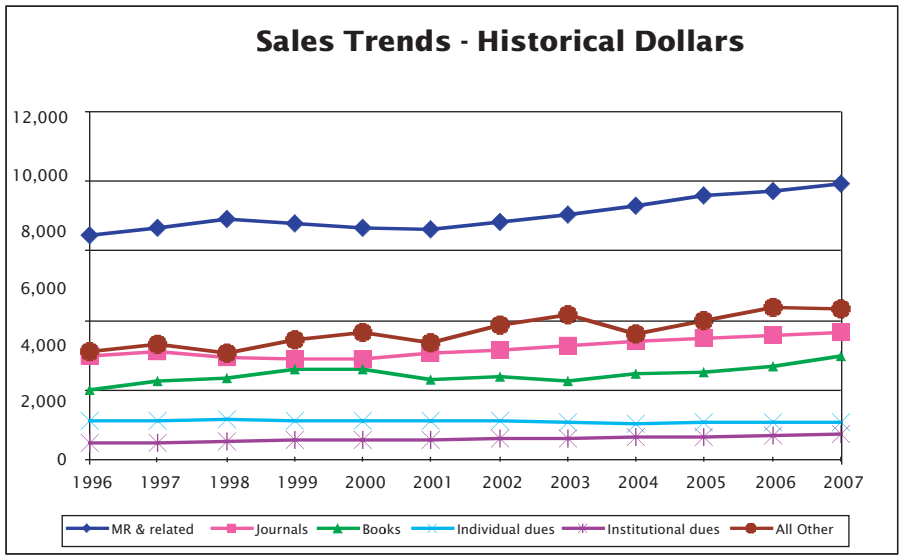


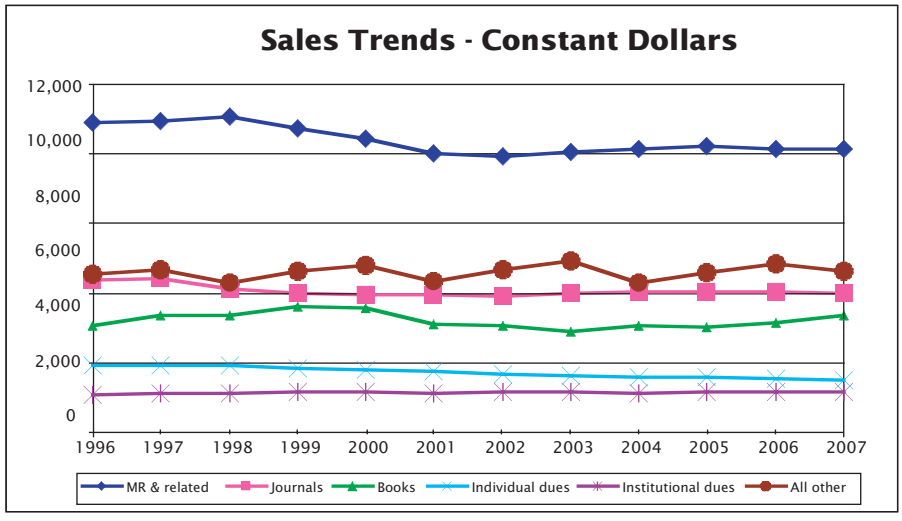


Unrestricted revenues in excess of unrestricted expenses for the year ended December 31, 2007, resulted in an increase in unrestricted net assets of approximately $5,105,000. Of this amount, operating activities provided approximately $2,685,000 and the return on the unrestricted portion of the long-term investment portfolio totaled approximately $2,420,000. The overall return on the Society's long-term investment portfolio was 5.4% in 2007 versus 13.6% in 2006. The problems with sub-prime mortgage loans first came to light in August 2007 and have led to a significant contraction in lending and financial difficulties for many banks and other financial institutions that continue in 2008. These and other matters are discussed in more detail in the following sections.

Unrestricted net assets also increased at the end of 2007 due to the implementation of a new accounting pronouncement related to the Society's post-retirement health benefit plan, in the amount of approximately $751,000. Under previous accounting rules, the amount required to be recorded as the liability for these benefits

was not the accumulated plan benefit obligation (APBO) as estimated by the plan's actuary, as gains and losses from plan amendments and/or actual experience being different from plan assumptions were required to be deferred and recognized in the annual benefit expense, and thus the liability, over an appropriate period of time. Under the new accounting rules, these gains and losses are still recognized in the annual expense, but the liability must be stated at the plan's APBO as determined by its actuary. Accordingly, there was an entry directly in unrestricted net assets in 2007 to adopt the new rules and adjust the liability to be equal to the APBO. For the Society, this was a reduction in the recorded liability and an increase in net assets. In future years, there will continue to be entries directly in unrestricted net assets which essentially reverse the effects of the amortizations of the gains and losses that are included in the annual expense, included in operating results.





The Society's net assets totaled $79,897,000 at December 31, 2007. $3,835,000 is permanently restricted, consisting of the original amount of donor restricted gifts and bequests received by the Society, as required under current accounting and legal guidance. $1,909,000 is temporarily restricted by donor-imposed limitations that will lapse upon the passage of time or the use of the assets for their intended purposes. $74,153,000 is unrestricted, of which $63,524,000 has been designated by the Board of Trustees as reserved for specific purposes in four distinct funds: the Economic Stabilization Fund (ESF), the Operations Support Fund (OSF), the Journal Archive Fund, and the Young Scholars Fund. The ESF's purpose is to provide a source of cash in the event of a financial crisis. The Society's Board of Trustees set the target at which to maintain the ESF at the sum of 75% of annual operating expenses plus the current estimate of the post-retirement health benefit plan's APBO. The OSF is used to provide operating income to the Society via the use of a spending rate, currently set by the Board at 5%. At the end of each year, the ESF and OSF are rebalanced so that the ESF is set at its target level. This was first done at the end of 2006 under the new Board policy. The rebalancing at the end of 2006 and 2007 moved funds from the ESF to the OSF of approximately $13,032,000 and $1,117,000, respectively. The Journal Archive Fund was established by the Board to accumulate funds to be able to convert the Society's journal data into new formats that may be developed and become standard for the dissemination of information in future years. The Young Scholars Fund was established by the Board to supplement the funds raised in the Epsilon true endowment fund, whose purpose is to support educational programs for young people interested in mathematics. The remaining unrestricted net assets consist of $4,271,000 invested in fixed assets and undesignated net assets of $6,358,000.

II. Review of 2007 Operations

As indicated in the graph on the preceding page, the past five years have been very good years, financially, for the Society.

The returns on long-term investments have been volatile over this period, with the average annual rate of return for the five and ten year periods ending December 31, 2007, at 12% and 6%, respectively. These returns, net of spendable income, have helped the endowment funds (and the income they produce) keep up with inflation.

Since 2002, the Board of Trustees has appropriated investment income from the OSF, as well as those true endowment funds with income whose use is

unrestricted, to support operations. The total amounts of such appropriations that have been included in operating revenue are $1,007,069 in 2007, $899,630 in 2006, $847,225 in 2005, $792,870 in 2004 and $865,696 in 2003.

This percentage relationship of operating income to total operating revenue has shown much more stability in the most recent eleven years compared to the first seventeen years, which is a positive financial indicator. General inflation is currently rising while investment returns are currently negative, so the larger of these percentages in the last eleven years may not be seen again for some time.

Sales Trends

The graphs on the preceding page show sales trends from 1996 through 2007, first in historical dollars and second in constant dollars (using 2007 as the base year and adjusting other years for inflation).

The trends shown in historical dollars are in general mildly upward, and this is partly due to pricing strategies that are intended to help counter the effects of inflation and attrition. When shown in constant dollars, most sources of revenue are fairly flat or declining over this period.

During the ten-year period from 1997 through 2007, the average annual inflation was 2.68%. During this same period, the Society's average annual expense growth was 1.77%, indicating that the Society was able to keep its expense growth about 0.9% below the rate of inflation for each year in this time period. This is indicative of the productivity gains experienced by the Society, due in large part to the improvements in the computing industry adopted by the Society. At the same time, the average annual growth in revenue was 2.01%. While the revenue growth did not keep up with inflation during this period, it was almost 25 basis points better than that of the expense growth rate. This positive differential was achieved during the same period of time when price increases on journals and MR products were lowered (the DAF had no price increase for one year), sectional meeting fees were held constant and individual dues were frozen for two years. In constant dollar terms, both revenues and expenses declined during this ten-year period, by an average annual rate of (0.53%) and (0.77%), respectively, in historical dollars. If the Board had not appropriated investment income to support operations (commencing in 2002), there would have been a negative difference between the growth of expenses and revenues of 0.17% annually during this ten-year period (expenses rising faster than revenues).

Mathematical Reviews. Total revenue from MR in its various forms increased from 2006, by approximately 3.2%. This is due to price increases effective in 2007, net of attrition (which was minor overall). Subscribers to paper MR products continue to decrease each year. Accordingly, the Society focuses its marketing efforts on its electronic delivery products, particularly concentrating on working with consortia, where costs can be spread over a larger number of institutions. This has the effect of providing the MR product line to a much wider audience than could afford it as individual institutions, as well as protecting the current revenue stream for future years. MR is currently financially healthy; however, as was seen in 2007, it is probably unrealistic to expect significant increases in sales revenue from additional subscribers.

Journals. The increase in journal revenues for 2007 provided only slightly more revenue than in 2006 due to the effects of attrition in subscribers, on an overall basis. While attrition had been less than expected in the last few years, it picked up again in 2007. Given the current economic environment and the pressures that will likely increase on academic institutions with these deteriorating conditions, it is possible that attrition could accelerate in the next few years. The financial solvency of subscription agents continues to be a worry to scholarly publishers. We experienced the bankruptcy of one subscription agent in 2003 and in 2004 a subscription agent with significant market share required the infusion of additional capital from investors in order to meet its obligations to subscribers and publishers. In early 2007 a Korean subscription agent went into bankruptcy; but this caused no economic harm to the Society. We have noticed significantly later payments from subscription agents for the 2008 renewals, which could indicate cash flow problems for them. With the advent of electronically available content directly from publishers, as well as a tarnishing of their industry in general from those who have taken subscribers' money without providing the related subscriptions due to financial difficulties in recent years, subscription agents are struggling to re-define themselves in the scholarly publications marketplace.

Books. Book revenues increased by approximately $401,000 or slightly over 12% in 2007 historical dollars, and by almost 8.6% in constant dollars. New titles produced totaled 100 versus 110 budgeted for 2007 and 102 in 2006. Sales of new and backlist titles continue to strengthen, with backlist sales comprising 35% of total sales on a unit basis. Unit sales climbed to 86,394 from 73,928 in 2005 while revenue per book sold remained steady over this period. This indicates the increased sales are not coming at the cost of deeper discounts. The Society continues to work with distributors and continues to improve marketing efforts in order to keep the book program as healthy as possible. It will move to a new European distributor in the latter part of 2008, which is expected to give the book program significantly more visibility in this market.

Dues. Dues, the sum of individual and institutional, have shown a slight upward slope on the historical dollars chart and a flat or slightly decreasing line in constant dollars. A flat constant dollar line is expected for institutional dues, as the number of members generally varies little from year to year and the dues rates have been set so that dues will increase at about the same level as inflation. There has been a decline in individual dues from their high in 1998. To date, the various programs implemented by the Society to improve its individual membership population have not been successful enough to overcome the steady erosion in members, and the annual dues increase has not maintained steady dues revenue in constant dollars.

Major Expense Categories.

The table above right shows the major expenses for 2005, 2006, and 2007, in thousands of dollars. There has not been much change from year to year in the types of

Major Expense Categories

	2005		2006		2007	
Personnel Costs	$14,608	66%	$15,471	67%	$15,607	68%
Building and equipment related	1,389	6%	1,359	6%	1,453	6%
Postage	865	4%	904	4%	982	4%
Outside printing, binding, and mailing	806	4%	876	4%	654	3%
Travel: staff, volunteers, grant supported	972	4%	1,131	5%	735	3%
All other expenses	3,557	16%	3,371	14%	3,400	16%
TOTAL	$22,197	100%	$23,112	100%	$22,831	100%

expenses incurred by the Society, which is expected as there have been no major changes in the way the Society operates.

Operating expenses can also be associated with the various activities of the Society, and this is how our audited financial statements are presented (see Section 4). The Society has accounting systems in place to capture the identifiable direct costs of its publishing and member and professional services activities, as well as indirect costs associated with these two major functions. General and administrative costs are those that cannot be directly associated with either of its two main functions or any activity therein. The following is a summary presentation that matches the revenue and costs of the major activities of the Society, derived directly from its audited financial statements.

Some points worth noting in the presentation below are that the *Mathematical Reviews* activities and the Providence publications produce similar margin (in dollars) after identifiable direct costs associated with these products. The indirect costs associated with the overall publishing activities of the Society (taking orders, shipping and storing goods, marketing and sales efforts, etc.) reduces this margin by 37%. If general and administrative were allocated to the publishing activities, this margin would be reduced even further. But there would still be significant margin from Publications, available to spend on services and outreach activities.

The member and professional services activities use resources of the Society, which are then supported, or "paid for" by member dues, spendable income from reserve and endowment funds, and the margin from publishing activities. While the various activities in this functional area do have revenue streams, such as fees, grant support, prize fund spendable income, etc., the costs incurred by

2007 Operating Revenue and Expenses by Major Activity, in Thousands of Dollars

	Revenue	Expense	Net
Publications:			
Mathematical Reviews	$ 9,747	$ 6,116	$ 3,631
Providence publications (books, journals, etc.)	8,725	4,552	4,173
Publications indirect (customer services, marketing, distribution and warehousing, etc.)		2,908	(2,908)
Total publications	18,472	13,576	4,896
Member and professional services:			
Services and outreach programs	1,320	3,350	(2,030)
Grants, prizes and awards	550	754	(204)
Meetings	909	941	(32)
Divisional indirect		555	(555)
Governance		400	(400)
Total before spendable income and dues revenue	2,779	6,000	(3,221)
Spendable income from investments	918		918
Dues	2,290		2,290
Total member and professional services	5,987	6,000	(13)
Other	1,056	57	999
General and administrative		3,197	(3,197)
Total	$25,515	$22,830	$ 2,685

these activities are significantly greater than the revenues generated.

III. Assets and Liabilities

So far, this report has dealt with revenues and expenditures that affect unrestricted net assets. Another aspect of the Society's finances is what it owns and owes, or its assets and liabilities, which are reported below in the Balance Sheets. As discussed previously, the Society's net assets and activities that increase or decrease net assets are classified as unrestricted, temporarily restricted, or permanently restricted. A majority of the assets and liabilities detailed on the accompanying Balance Sheets constitute the unrestricted net assets. The permanently restricted net assets are supported by investments in the long-term investment portfolio and the temporarily restricted net assets are supported by investments in the long-term and short-term investment portfolios. The Market Value of Invested Funds shows the market value of each endowment and Board designated (quasi-endowment) fund, including any reinvested earnings.

The Society's fiscal year is the calendar year and thus coincides with the period covered by subscriptions and dues. Since dues and subscriptions are generally received in advance, the Society reports a large balance of cash and short-term investments on its financial statements at year-end. This amounted to approximately $17,309,000 and $18,614,000 at December 31, 2007, and 2006, respectively. The corresponding liability for the revenues received in advance was approximately $12,336,000 and $12,908,000 at December 31, 2007, and 2006, respectively.

The Society's property and equipment include land, buildings and improvements, office furniture and equipment, and software. The Society also owns a small amount of transportation equipment. The land, buildings, and improvements include the Society's Rhode Island headquarters, with buildings in Providence and Pawtucket, and the *Mathematical Reviews* offices in Ann Arbor. The largest part of the Society's office equipment is its investment in computer facilities. Generally accepted accounting principles require that investments in property, plant, and equipment used for operations be stated at cost, less accumulated depreciation. It is likely that the value of the land and buildings owned by the Society is significantly greater than the net amount recorded as assets (approximately $4,271,000 at December 31, 2007).

Capital additions increased from approximately $333,000 in 2006 to slightly over $752,000 in 2007, and are expected to be approximately $1,011,000 in 2008. Investments are being made in the Society's facilities such as replacements to the heating, ventilation and air conditioning equipment, roof replacement, renovations to working space, and upgrading its management software applications to current technology.

An important feature to note on the Society's balance sheet is that the Society owes no debt to third parties, other than the normal liabilities incurred in operations such as those owed to employees, vendors, and the deferred revenue for payments received in advance from members, subscribers, and other customers. This means that the Society owns all of its assets free and clear of any encumbrances, liens, or other types of impairments typically associated with debt. This is not expected to change, despite the significant planned internal investments in the next few years and the deteriorating economic conditions.

The Society's endowment is managed under the "total return concept". Under this management policy, income in excess of a reasonable amount (set by the Board of Trustees) is reinvested and increases the value of the fund. This allows for growth in income over time, intended to maintain the "purchasing power" of the original gifts steady over the long term. As discussed previously, in 2002 the Board of Trustees established a policy of annually appropriating investment income from those true endowment funds whose use of income is unrestricted and from the Operations Support Fund to support operations. The amount of such appropriations included in operating revenue is $1,007,069 and $899,630 in 2007 and 2006, respectively.

IV. Summary Financial Information

The following Balance Sheets and Statements of Activities are from the audited annual financial statements of the Society, and the Statement of Invested Funds is from the internal financial records of the Society. Each year, the Audit Committee of the Board of Trustees meets with the Society's auditors to review the conduct of the audit, the Society's financial statements, and the auditors' report on the financial statements. Pursuant to the recommendation of the Audit Committee, the Board of Trustees has accepted the audited financial statements. A copy of the Society's audited financial statements, as submitted to the Trustees and the Council, will be sent from the Providence Office to any member who requests it from the treasurer. The treasurer will be happy to answer any questions members may have regarding the financial affairs of the Society.

—Respectfully submitted,

John M. Franks
Treasurer

BALANCE SHEETS
December 31, 2007, and 2006

Assets	2007	2006
Cash and cash equivalents	$ 921,425	$ 1,518,285
Short-term investments	16,387,716	17,095,580
Receivables, less allowances of $260,000 and $250,000 respectively	1,409,424	1,607,714
Deferred prepublication costs	608,723	580,769
Completed books	1,153,060	1,060,636
Prepaid expenses and deposits	1,323,430	1,172,409
Land, bldgs. and equipment, less accumulated depreciation	4,270,952	3,734,674
Long-term investments	74,065,208	68,461,186
Total assets	**$100,139,938**	**$95,231,253**

Liabilities and Net Assets		
Liabilities:		
Accounts payable	$ 1,446,840	$ 1,534,995
Accrued expenses:		
Severance and study leave pay	1,213,114	1,147,066
Payroll, benefits, and other	1,167,720	994,608
Deferred revenue	12,335,892	12,907,692
Postretirement benefit obligation	4,079,327	4,706,688
Total liabilities	**20,242,893**	**21,291,049**
Net assets:		
Unrestricted	74,152,965	59,769,368
Temporarily restricted	1,908,841	1,794,484
Permanently restricted	3,835,239	3,473,711
Total net assets	**79,897,045**	**65,037,563**
Total liabilities and net assets	**$100,139,938**	**$84,704,245**

STATEMENTS OF ACTIVITIES
Years Ended December 31, 2007, and 2006

Changes in unrestricted net assets:

Operating Revenue	2007	2006
Publication:		
Mathematical Reviews and related activities	$ 9,747,337	$ 9,444,936
Journals (excluding MR)	4,481,903	4,407,455
Books	3,693,828	3,293,020
Sale of services	411,763	385,855
Other	137,369	142,632
Total publication revenue	18,472,200	17,673,898
Membership and professional services:		
Dues, services, and outreach	3,609,792	3,583,116
Grants, prizes, and awards	550,202	881,496
Investment earnings available for spending	917,949	819,630
Meetings	908,836	893,202
Total membership and professional services revenue	5,986,779	6,177,444
Short-term investment income	895,022	756,686
Other	161,156	152,355
Total operating revenue	**$25,515,157**	**$24,760,383**

Operating Expenses		
Publication:		
Mathematical Reviews and related activities	$ 6,115,797	$ 6,133,098
Journals (excluding MR)	1,351,788	1,293,764
Books	2,957,073	2,926,057
Publication–divisional indirect	955,416	805,909
Warehousing and distribution	889,903	857,274
Customer services	814,685	848,861
Marketing and sales	248,330	232,922
Sale of services	243,109	251,747
Total publication expense	13,576,101	13,349,632
Membership and professional services:		
Dues, services, and outreach	3,350,117	3,539,475
Grants, prizes, and awards	754,103	1,190,011
Meetings	940,853	916,111
Governance	400,390	417,497
Divisional indirect	554,806	441,759
Total membership and professional services expense	6,000,269	6,504,853
Other	57,384	142,711
General and administrative	3,196,735	3,114,916
Total operating expenses	**$22,830,489**	**$23,112,112**
Excess of operating revenue over operating expenses	$2,684,668	$1,648,271
Long-term investment return in excess of investment earnings available for spending	2,420,182	6,879,748
Effect of adoption of SFAS 158	750,728	—
Change in unrestricted net assets	**5,855,578**	**8,528,019**

	2007	2006
Changes in temporarily restricted net assets:		
Contributions and grants	53,952	52,971
Long-term investment income (loss)	200,215	420,472
Net assets released from restrictions	(310,704)	(302,549)
Change in temporarily restricted net assets	**(56,537)**	**170,894**
Change in permanently restricted net assets—Contributions	**157,800**	**203,728**
Change in net assets	5,956,841	8,902,641
Net assets, beginning of year	73,940,204	65,037,563
Net assets, end of year	**$79,897,045**	**$73,940,204**

STATEMENTS OF INVESTED FUNDS
As of December 31, 2007, and 2006

	Dec. 31, 2007		Dec. 31, 2006
	Original Gift(s)	Market Value	Market Value
Endowment Funds:			
Prize Funds:			
Steele	$145,009	$ 654,511	$ 647,897
Birkhoff	40,076	70,675	39,195
Veblen	2,000	13,372	13,237
Wiener	2,000	13,372	13,237
Bôcher	1,450	9,725	9,627
Conant	9,477	43,650	43,209
Cole	5,550	22,965	22,732
Satter	15,000	34,764	34,412
Morgan	25,000	47,502	47,022
Whiteman	63,468	71,837	71,111
Doob Book Prize	45,000	50,867	52,504
Robbins Prize	40,500	46,719	47,719
Eisenbud	40,000	43,920	43,476

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Deadline for registration December 12, 2008

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STATEMENTS OF INVESTED FUNDS, CON'T.
As of December 31, 2007, and 2006

	Dec. 31, 2007 Original Gift(s)	Dec. 31, 2007 Market Value	Dec. 31, 2006 Market Value
Arnold Ross Lectures	70,000	79,932	79,125
Trjitzinsky Scholarships	196,030	526,243	520,924
C. V. Newsom	100,000	244,885	242,410
Centennial Fellowship	56,100	125,561	124,292
Menger	9,250	12,288	12,164
Ky Fan (China)	366,757	387,085	383,173
Epsilon	1,037,431	1,167,541	1,030,659
Total Income Restricted Funds	$2,270,098	$3,667,413	$3,478,125
Endowment	100,240	805,476	797,059
Morita	100,000	143,694	142,234
Henderson	548,223	4,316,561	4,272,703
Schoenfeld/ Mitchell	573,447	809,829	801,601
Laha	189,309	273,133	270,358
Ritt	51,347	257,174	254,561
Moore	2,575	24,242	23,996
Total Income Unrestricted Funds	1,565,141	6,630,110	6,562,512
Total Endowment Funds	$3,835,240	$10,297,523	$10,040,637
Board-Restricted Funds:			
Journal Archive		677,039	599,289
Young Scholars		689,014	653,985
Economic Stabilization		21,326,742	21,302,648
Operations Support		40,830,813	35,571,266
Total Board-Restricted Funds		63,523,608	58,127,188
Total Funds		$73,821,130	$68,167,825

From the AMS Secretary

ATTENTION ALL AMS MEMBERS

Voting Information for 2008 AMS Election

AMS members who have chosen to vote online will receive an **email message** on or shortly after August 18, 2008, **from the AMS Election Coordinator, Survey & Ballot Systems**.

The From Line will be "AMS Election Coordinator".

The Sender email address will be `amsvote@directvote.net`.

The Subject Line will be "AMS 2007 Election—login information below".

The body of the message will provide your unique voting login information and the address (URL) of the voting website. **If you use a spam filter, you may want to use the above address or subject information to configure your spam filter to ensure this email will be delivered to you.**

AMS members who have chosen to vote by paper should expect to receive their ballot by the middle of September. Unique voting login information will be printed on the ballot should you wish to vote online.

At midnight (U.S. Eastern Daylight Saving Time) on November 2, 2008, the website will stop accepting votes. Paper ballots received after this date will not be counted.

Additional information regarding the 2008 AMS Election is available on the AMS website, `http://www.ams.org/secretary/election-info.html`, or by contacting the AMS: `election@ams.org`, 800-321-4267 (U.S. & Canada), 401-455-4000 (worldwide).

Thank you and please remember to vote.

—Robert J. Daverman

ASSOCIATE SECRETARY
Central Section

Position

The American Mathematical Society is seeking applications and nominations of candidates for the post of Associate Secretary of the Central Section. Susan J. Friedlander, current Associate Secretary there, wishes to step down at the end of her present term.

An Associate Secretary is an officer of the Society and is appointed by the Council to a two-year term, ordinarily beginning on 01 February. In this case the term should begin 01 February 2010 and end 31 January 2012. Reappointments are possible and desirable. All necessary expenses incurred by an Associate Secretary in performance of duties for the Society are reimbursed, including travel and communications.

Duties

The primary responsibility of an Associate Secretary is to oversee scientific meetings of the Society in the section. Once every four years an Associate Secretary has primary responsibility for the Society's program at the January Joint Mathematics Meeting. An Associate Secretary is a member of the Secretariat, a committee consisting of all Associate Secretaries and the Secretary, which approves all applications for membership in the Society and approves all sites and dates of meetings of the Society. Occasionally an Associate Secretary is in charge of an international joint meeting. Associate Secretaries are the principal contact between the Society and its members in the various sections. They are invited to all Council meetings and have a vote on the Council on a rotating basis.

Applications

An Associate Secretary is appointed by the Council upon recommendation by the Executive Committee and Board of Trustees. Applications should be sent to:

Robert J. Daverman, Secretary, American Mathematical Society,
312D Ayres Hall, University of Tennessee, Knoxville TN 37996-1330

email: daverman@math.utk.edu

Applications received by 15 September 2008
will be assured full consideration.

AMS
American Mathematical Society
www.ams.org

Mathematics Calendar

Please submit conference information for the Mathematics Calendar through the Mathematics Calendar submission form at `http://www.ams.org/cgi-bin/mathcal-submit.pl`. The most comprehensive and up-to-date Mathematics Calendar information is available on the AMS website at `http://www.ams.org/mathcal/`.

August 2008

* 6–10 **BLAST**, University of Denver, Denver, Colorado.
Description: BLAST is a new conference focusing on Boolean Algebras, Lattices, Algebraic Logic, Universal Algebra, Set Theory, Set-theoretic Topology and Point-free Topology.
Plenary Speakers: Bernhard Banaschewski (McMaster University); James Cummings (Carnegie Mellon University); Mai Gehrke (Radboud Universiteit Nijmegen); Martin Goldstern (Technische Universität Wien); Tetsuya Ishiu (Miami University); Ales Pultr (Charles University); Judy Roitman (University of Kansas); Kazushige Terui (National Institute of Informatics, Japan); Constantine Tsinakis (Vanderbilt University).
Tutorials: Algebra of Logic: James Raftery (University of Kwazulu-Natal); Set Theory: Katie Thomson (Universität Wien); Set-theoretic Topology: Peter Nyikos (University of South Carolina); Universal Algebra: Matt Valeriote (McMaster University); Mini Course: Forbidden Configurations in Lattices: Richard Ball and Ales Pultr; Local Organizing and Program Committee: Richard Ball, Natasha Dobrinen (Co-chair), Nikolaos Galatos (Co-chair).
Information: email: `ngalatos@du.edu`; `http://www.math.du.edu/blast`.

* 25–27 **Groups and Infinite Graphs**, Erwin Schrödinger International Institute, Vienna, Austria.
Scientific committee: Bernhard Krön (local organizer, University of Vienna, Austria); Bojan Mohar (Simon Fraser University, BC, Canada); Wolfgang Woess (Graz University of Technology, Austria).
Topics: Geometric group theory, group actions on graphs, infinite graph theory.
Talks: If you want to contribute a talk, please send title and abstract to `bernhard.kroen@univie.ac.at` by friday May 30, 2008. We will only have a restricted number of talks, because there should be time for discussions and work in smaller groups. Every participant will have the opportunity to present a poster.
Support: There is no conference fee, but the possibilities of financial support are very limited.
Information: email: `bernhard.kroen@univie.ac.at`; `http://homepage.univie.ac.at/bernhard.kroen/groups_graphs/index.html`.

* 27–29 **1st Workshop in Stochastic Modeling**, Universidade de Sao Paulo Ribeirão Preto, Sao Paulo, Brazil.
Description: The workshop is intended as 1) a forum to discuss new developments in stochastic modeling and its applications, 2) an occasion to detect new directions of research in probability and stochastic processes, 3) an opportunity to establish new collaborations, 4 an opportunity for the students to begin their scientific life.
Information: `http://dfm.ffclrp.usp.br/mat/wsm1`; email: `fmachado@ime.usp.br`.

* 28–30 **The 4th William Rowan Hamilton Geometry and Topology Workshop Heegaard splittings, mapping class groups, curve complexes and related topics**, Hamilton Mathematics Institute (HMI), Trinity College, Dublin, Ireland.
Description: This is an announcement for the 4th William Rowan Hamilton Geometry and Topology Workshop to be held at the Hamilton Mathematics Institute (HMI), in Trinity College, Dublin, Ireland. This year, the workshop runs from Thursday, August 28th, through Saturday, August 30th.

This section contains announcements of meetings and conferences of interest to some segment of the mathematical public, including ad hoc, local, or regional meetings, and meetings and symposia devoted to specialized topics, as well as announcements of regularly scheduled meetings of national or international mathematical organizations. A complete list of meetings of the Society can be found on the last page of each issue.
An announcement will be published in the *Notices* if it contains a call for papers and specifies the place, date, subject (when applicable), and the speakers; a second announcement will be published only if there are changes or necessary additional information. Once an announcement has appeared, the event will be briefly noted in every third issue until it has been held and a reference will be given in parentheses to the month, year, and page of the issue in which the complete information appeared. Asterisks (*) mark those announcements containing new or revised information.
In general, announcements of meetings and conferences carry only the date, title of meeting, place of meeting, names of speakers (or sometimes a general statement on the program), deadlines for abstracts or contributed papers, and source of further information. If there is any application deadline with respect to participation in the meeting, this fact should be noted. All communications on meetings and conferences in the mathematical sciences should be sent to the Editor of the *Notices* in care of the American Mathematical Society in Providence or electronically to `notices@ams.org` or `mathcal@ams.org`.
In order to allow participants to arrange their travel plans, organizers of meetings are urged to submit information for these listings early enough to allow them to appear in more than one issue of the *Notices* prior to the meeting in question. To achieve this, listings should be received in Providence **eight months** prior to the scheduled date of the meeting.
The complete listing of the Mathematics Calendar will be published only in the September issue of the *Notices*. The March, June/July, and December issues will include, along with new announcements, references to any previously announced meetings and conferences occurring within the twelve-month period following the month of those issues. New information about meetings and conferences that will occur later than the twelve-month period will be announced once in full and will not be repeated until the date of the conference or meeting falls within the twelve-month period.
The Mathematics Calendar, as well as Meetings and Conferences of the AMS, is now available electronically through the AMS website on the World Wide Web. To access the AMS website, use the URL: `http://www.ams.org/`.

Topic: This year's topic is Heegaard splittings, mapping class groups, curve complexes and related topics.
Funding and Sponsors: The workshop is co-sponsored by Boston College, and the HMI. A limited amount of funding is available for both junior and senior researchers wishing to attend.
Information: http://www.hamilton.tcd.ie/events/gt/gt2008.htm; email: bridgem@bc.edu.

* 29–September 2 **The International Conference of Differential Geometry and Dynamical Systems (DGDS-2008) & the V-th International Colloquium of Mathematics in Engineering and Numerical Physics (MENP-5, mathematics sections)**, Mangalia, Romania.
Description: The Conference main topics are: 1. Applications of Riemannian and Finsler-Lagrange-Hamilton structures; 2. Dynamical systems and jet space theory; 3. Multitime evolutions and optimal control problems; 4. Magnetic dynamical systems; antennas theory; 5. Mathematical models in Physics and in Engineering; 6. Mathematical statistics; 7. Chaos and fractals. Graduate students and postdocs interested in these rapidly developing fields are warmly welcome.
Information: email: vbalan@mathem.pub.ro; http://www.mathem.pub.ro.

* 30–31 **2008 Annual Convention—Mathematics Teachers Association of the Philippines—Tertiary Level Chapter**, Iloilo City, Philippines.
Description: The Convention with the Theme "Advancing Mathematics through Country's Development" hopes to bring together mathematics educators and researchers, and teachers in the country to discuss the current issues and trends in the teaching and assessment of mathematics learning. This convention is fully endorsed by the Commission on Higher Education.
Information: email: adiansuy@gmail.com.

September 2008

* 8–9 **Drexel University Workshop on Topology and Physics**, Departments of Mathematics and Physics, Drexel University, Philadelphia, Pennsylvania.
Description: The purpose of the workshop is to bring together mathematicians, physicists, and students interested in the interaction between topology and physics. Six invited lectures will describe various classical and current aspects of this interaction at a level appropriate to an audience of non-specialists. Poster sessions and extended discussion periods will provide the opportunity for participants to exchange ideas and establish contacts and collaborations.
Invited speakers include: Tony Pantev (University of Pennsylvania), Amir Hajian (Princeton University), Wilma Olson and Irwin Tobias (Rutgers University), Robert Gilmore (Drexel University), Eric Sharpe (Virginia Tech), and Randall D. Kamien (University of Pennsylvania).
Information: http://www.pages.drexel.edu/~gln22/Workshop.htm; email: gln22@drexel.edu.

* 8–10 **GLAM, Global Analysis on Manifolds**, University of Rome "La Sapienza", Rome, Italy.
Description: On the occasion of the 60th birthday of Sylvestre Gallot.
Scientific Committee: V. Ancona (Italy, Univ. Firenze), W. Ballmann (Germany, Univ. Bonn), P. Berard (France, Institut Fourier), J. P. Bourguignon (France, CNRS-IHES - Bures-sur-Yvette), J. Cheeger (U.S.A., N.Y.U.), H. Karcher (Germany, Univ. Bonn), S. Marchiafava (Italy, Univ. Roma La Sapienza), S. Salamon (Italy, Politecnico Torino).
Organizing Committee: G. Besson (France, Institut Fourier), M. Bordoni (Italy, Univ. Roma La Sapienza), G. D'ÒAmbra (Italy, Univ. Cagliari), A. El Soufi (France, Univ. Tours), B. Franchi (Italy, Univ. Bologna), R. Grimaldi (Italy, Univ. Palermo), O. Hijazi (France, Univ. Nancy), A. Sambusetti (Italy, Univ. Roma La Sapienza), A. Savo (Italy, Univ. Roma La Sapienza).
Information: http://www.dmmm.uniroma1.it/glam; email: leon@dmmm.uniroma1.it.

* 17–19 **First Summer School on Copulas**, Johannes Kepler University, Linz, Austria.
Description: The Summer School aims at providing a meeting point for exchanging ideas and presenting new directions on the theory of copulas and related applications.
Information: http://www.flll.jku.at/ssc; email: fabrizio.durante@jku.at.

* 26–28 **Fourth Yamabe Symposium: "Geometry and Analysis"**, School of Mathematics, University of Minnesota, Minneapolis, Minnesota.
Confirmed speakers are: Simon Brendle, Stanford University; Alice Chang, Princeton University; Gerhard Huisken, Albert Einstein Institute, Potsdam; Ngaiming Mok, Hong Kong University; Leon Simon, Stanford University; Yum-Tong Siu, Harvard University; Neil Trudinger, Australian National University; and Burkhard Wilking, University of Muenster.
Support: From the National Science Foundation will be used to defray workshop expenses for a number of participants, with highest preference given to younger scientists (grad students, postdocs, young faculty or researchers at most five years after Ph.D.), although all active people are eligible. Women and minorities are especially encouraged to apply.
Deadline: The application deadline for full consideration for funding is Thursday, August 7, 2008.
Information: http://www.math.umn.edu/yamabe/; email: gulliver@math.umn.edu.

* 27 **Illinois/Missouri Applied Harmonic Analysis Seminar**, Southern Illinois University, Edwardsville, Illinois.
Description: The Seminar is an ongoing sequence of meetings fostering research interactions among mathematicians, engineers, and physicists who develop and apply techniques from harmonic analysis.
Theoretical topics of interest include: Wavelets, Gabor systems (time-frequency analysis), frames and Riesz bases, approximation theory, X-ray type transforms.
Applications of interest include: All kinds of signal and image analysis, processing and reconstruction, both analogue and digital.
Support: This conference is supported in part by the National Science Foundation and the Institute for Mathematics and its Applications (IMA) through its Participating Institution (PI) Program. PI members may use IMA/PI funds to support travel of their personnel to this conference.
Registration: Conference registration is free, and all interested researchers are invited to attend.
Information: For more information, please visit the conference website or contact the local organizer: Myung-Sin Song; msong@siue.edu; http://www.siue.edu/~msong/IMAHA/IMAHA4.html.

October 2008

* 6–10 **Partial differential equations and differential Galois theory: A conference on the occasion of the 80th birthday of Bernard Malgrange**, Centre International de Rencontres Mathématiques (CIRM), Marseille, France.
Description: The purpose of this meeting is to exchange ideas on algebraic structures of Pde's going back to Elie Cartan, Lie and Galois while celebrating the birthday of one of the most active mathematicians in this field. Main topics will be differential Galois theory, groupoids, Cartan's involutivity, non linear algebraic partial differential equations. The scientific committee is composed of L. Boutet de Monvel, J.P. Ramis, C. Sabbah and the two organizers Y. Laurent and L. Stolovitch.
Information: http://www.cirm.univ-mrs.fr/liste_rencontre/Rencontres2008/Renc319/Renc319.html; email: stolo@picard.ups-tlse.fr.

* 13–17 **Applications of Internet MRA to Cyber-Security**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.
Overview: Internet-security is a large and complex problem space with profound implications for our society. On one side are defenders who are responsible for creating systems, protocols, policies, and other mechanisms to protect an IT infrastructure from unwanted access. On the other side are attackers who conduct malicious activity in the Internet for recognition, profit, or more sinister reasons. This workshop will assemble a group of leading researchers and cyber-security professionals to discuss several key challenges for defenders.
Organizing Committee: Bill Aiello, Paul Barford, Tal Malkin, Niels Provos, Mike Reiter, Matthew Roughan.
Application/Registration: An application/registration form is available at http://www.ipam.ucla.edu/programs/mraws2/. Applications received by September 1, 2008 will receive fullest consideration. Encouraging the careers of women and minority mathematicians

and scientists is an important component of IPAM's mission and we welcome their applications.

* 20–22 **10th International Conference on Information and Communications Security (ICICS'08)**, Birmingham, United Kingdom.
Description: The event, which started in 1997, brings together individuals involved in multiple disciplines of Information and Communications Security, in order to foster the exchange of ideas.
Organizers: ICICS 2008 will be organized by the School of Computer Science, University of Birmingham, in co-operation with HP Laboratories (Bristol, UK), the UK Engineering and Physical Sciences Research Council (EPSRC), and the International Communications and Information Security Association (ICISA).
Information: email: a.j.brown@cs.bham.ac.uk; http://events.cs.bham.ac.uk/icics08/.

* 22–23 **DIMACS Workshop on Nanotechnology and Biology**, DIMACS Center, CoRE Building, Rutgers University, Piscataway, New Jersey.
Short Description: Recent years have witnessed the development of fabrication and characterization technologies to manipulate and analyze matter at the nanoscale. These technologies have applications in myriad areas, including in biology, where nature has evolved its own nanotechnologies that inspire many contemporary engineered nanodevices. As first generation nanotechnologies have provided proofs of principle for many exciting applications, the need for better understanding of biology and physics at the nanoscale through modeling and computation has become apparent. This workshop will explore the foundations of nanoscale assembly in natural and engineered systems. Natural systems may include viruses, organelles, or multi-molecular machines as they self-assemble and take shape in processes that might include, for example, development, adaptation, or cancer. Engineered systems under development include smart drug delivery systems, DNA-based fabrication, layer-by-layer assembly and electrospun nanofibers. The ability to model and understand the natural systems will accelerate the development of engineered nanosystems. While efforts to attain better understanding through modeling and computation are of primary interest, the integration of modeling and experiments is quite relevant and necessary to advance our understanding of self-assembly at the nanoscale. Because this field is so interdisciplinary, we envision an audience that includes biologists, chemists, physicists, computer scientists and engineers.
Organizers: Stan Dunn, Rutgers University; email: smd@occlusal.rutgers.edu; Yannis Androulakis, Rutgers University, email: yannis@rci.rutgers.edu; Charlie Roth, Rutgers University, email: cmroth@rci.rutgers.edu.
Local Arrangements: Workshop Coordinator, DIMACS Center, email: workshop@dimacs.rutgers.edu; 732-445-5928; http://dimacs.rutgers.edu/Workshops/Nanotechnology/index.html.

* 22–24 **Twenty-Second Midwest Conference on Combinatorics, Cryptography, and Computing (MCCCC)**, University of Nevada, Las Vegas (UNLV), Las Vegas, Nevada.
Description: The title of the conference is fairly descriptive of the subjects discussed.
Invited speakers: Gary Chartrand, Western Michigan University; Ronald Graham, University of California, San Diego; Spyros Magliveras, Florida Atlantic University; Doug Stinson, University of Waterloo, Canada; and Catherine Yan, Texas A&M University.
Talks: Twenty-minute contributed talks are invited.
Information: http://www.mcccc.info; email: ebrahim.salehi@unlv.edu.

* 27–29 **DIMACS Workshop on Models/Methodological Problems of Botanical Epidemiology**, DIMACS Center, CoRE Building, Rutgers University, Piscataway, New Jersey.
Description: Presented under the auspices of the Special Focus on Computational and Mathematical Epidemiology. This workshop will gather experts from the botanical epidemiology and genetics communities together with mathematicians interested in modeling using differential equations, discrete systems, and stochastic processes to investigate modeling and methodological problems of spread of disease in plants. The workshop will investigate modeling approaches including ode, pde, individual-based models including percolation, random graph, stochastic, spatially-explicit and spatially-implicit (moment closure and pairwise approximation) and metapopulation models. We will also discuss data and model testing issues, such as parameter estimation for spatially-explicit and spatially-implicit models with and without unobserved compartments; data collection for model testing and parameter estimation from lattice crops, row crops, continuum and mosaics; optimization of experimental design for parameter estimation and model discrimination; and analysis of microcosm data to distinguish demographic and environmental stochasticity.
Organizers: Chris Gilligan, Cambridge; cag1@cus.cam.ac.uk.
Local Arrangements: Workshop Coordinator, DIMACS Center, workshop@dimacs.rutgers.edu, 732-445-5928.
Information: http://dimacs.rutgers.edu/Workshops/Botanical/.

November 2008

* 3–7 **Beyond Internet MRA: Networks of Networks**, Institute for Pure and Applied Mathematics (IPAM), UCLA Los Angeles, California.
Overview: This workshop will bring together domain experts from the fields of engineering, biology, mathematics, and critical infrastructure protection to develop the foundation of a nascent theory in support of the networks of networks concept. In particular, we will use the Internet as a case study to illustrate how early verbal observations and arguments with deep engineering insight have led via an interplay with mathematics and measurements to increasingly formal statements and powerful theoretical developments.
Organizing Committee: Walter Willinger (chair), David Alderson, John Doyle, Ramesh Govindan, Craig Partridge.
Application/Registration: An application/registration form is available at http://www.ipam.ucla.edu/programs/mraws3/. Applications received by September 22, 2008, will receive fullest consideration. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications.

* 4–6 **Multi-Scale Phenomena In Biology**, OIST Seaside House, Okinawa, Japan.
Description: A multitude of biological phenomena are described at multiple levels. What are the commonalities and differences between neuroscience, evolutionary biology, molecular biology and ecology in this regard? How can mathematics help in describing these phenomena?
Confirmed Speakers: Bjorn Engquist; The University of Texas at Austin; Hans Othmer; University of Minnesota; Eric Vanden-Eijnden; Courant Institute; Keiko Takahashi, Earth Simulator Center; Dan Rockmore, Dartmouth College; Terry Sejnowski, Salk Institute; Diego Rasskin-Gutman, Konrad Lorenz Institute for Evolution and Cognition Research; Tony Bell, Redwood Center for Theoretical Neuroscience; Robert Warner, University of California; Walter R. Tschinkel, Florida State University; Klaus M. Stiefel, OIST.
Support: Travel scholarships are available. We encourage applications by graduate students and postdocs whose research interests touch these subjects. To apply please contact Ryoko Uchida or Shino Fibbs (multi@oist.jp).
Information: http://www.irp.oist.jp/tenu/multi.html.

* 7–9 **Applications of Geometry to Topology and Physics: A conference in honor of the 70th birthday of Herman Gluck**, Rutgers-Newark, Newark, New Jersey.
Description: This conference, in honor of the 70th birthday of Herman Gluck, will address two topics in the application of geometry to other fields: (1) calibrated geometry and its applications to physics; (2) the application of geometry to knot theory, including topics such as Freedman's Mobius energy and Nabutovsky's ropelength.
Speakers tentatively include: Thomas Banchoff, Jason Cantarella, Robert Connelly, Dennis DeTurck, David Gabai, Weiqing Gu, Blaine Lawson, David Singer, Dennis Sullivan, and Gang Tian.
Support: Some financial support is available.
Information: email: parslerj@wfu.edu; http://www.math.uga.edu/gluckfest.

* 11–14 **2nd International Conference of Young Mathematicians on Differential Equations and Applications dedicated to Ya. B. Lopatinskii**, Department of Differential Equations, Donetsk National University, Universitetskaya, 24, Donetsk, 83055, Ukraine.

Topics: General theory of boundary value problems for PDEs, Lopatinskii condition. Investigations of boundary value problems for classes of PDEs. Nonlinear PDEs, free boundary problems. Qualitative theory of PDEs. Differential and integral operators, operator methods, difference equations. Algebraic, geometrical and topological methods in the theory of ODEs and PDEs. Ordinary DEs, dynamical systems, optimal control. Mathematical physics and other applications of DEs in natural-science, technical and social studies.
Aim: Bringing together young and some venerable researchers in above areas in order to get acquainted, to communicate, and to understand what directions are actual and perspective. The word "young" in the title means a general direction of the conference but doesn't mean any age limitations for the participants.
Information: http://www.donnu.edu.ua/en/index.asp (then click button from conferenceannouncementinleft-side column); email: icde2008@matfak.dongu.donetsk.ua; tel: +38(062)3054628 +38(062)3029260; fax: +38(062)3054628.

* 17–21 **New Mathematical Frontiers in Network Multi-Resolution Analysis**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.
Description: This workshop will bring together researchers in mathematics, computer science, electrical engineering, and statistics to develop new mathematical foundations in network-centric multiresolution analysis and to explore and define new mathematical or algorithmic techniques in network MRA. These techniques include methods of analysis, representation, and synthesis of large networks, as well as visualization, analysis, and representation of network measurements.
Organizing Committee: Robert Calderbank, Anna Gilbert, Peter Jones, Steven Low, Matthew Roughan, Denis Zorin.
Application/Registration: An application/registration form is available at http://www.ipam.ucla.edu/programs/mraws4/. Applications received by October 6, 2008, will receive fullest consideration. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications.

December 2008

* 5–8 **International Conference on Partial Differential Equations and Applications in honour of Professor Philippe G. Ciarlet's 70th birthday**, City University of Hong Kong, Kowloon, Hong Kong.
Description: The objectives of the Conference are to review and discuss some of the latest trends in the field of partial differential equations and applications. The conference is dedicated to Professor Philippe G. Ciarlet, professor emeritus, Université Pierre et Marie Curie, and chair professor, City University of Hong Kong, on the occasion of his 70th birthday, in recognition of his mathematical achievements and of his dedication to the mathematical community.
Information: http://www6.cityu.edu.hk/rcms/ICPDEA2008/; email: mclbj@cityu.edu.hk.

* 19–21 **Centenary Celebration of Calcutta Mathematical Society: International Symposium on Recent Advances in Mathematics and its Applications: (ISRAMA 2008)**, Calcutta Mathematical Society at AE-374, Sector-1, Salt Lake City Kolkata (Calcutta) 700064, India.
Description: The Calcutta Mathematical Society is organizing an International Symposium on Recent Advances in Mathematics and its Applications (ISRAMA 2008) on occasion of its Centenary.
Topics: Algebra, discrete mathematics & theoretical computer science analysis & topology and their applications; geometry and its applications; dynamical systems; chaos and fractals continuum mechanics; plasma physics; control theory and optimization; theory bio-mechanics and bioinformatics; applications of mathematics to environmental problems; history and philosophy of physical science; quantum information; theory relativity and its applications.
Deadline: Last Date: August 31, 2008, for receipt of full paper along with an abstract and registration.
Information: email: cms.centenary@gmail.com; http://www.calmath.org/forthcoming.html.

* 22–23 **Mathematical Sciences for Advancement of Science and Technology (MSAST 2008)**, Institute for Mathematics, Bioinformatics, Information Technology and Computer Science (IMBIC), Salt Lake City, Kolkata (Calcutta), India.
Call for Papers: Authors are requested to submit the full paper related to the theme of the Conference: "Mathematical Sciences for Advancement of Science and Technology" with an abstract indicating the motivation of the problem, its method of solution and important results to the Secretary of IMBIC. All the papers are to be screened for presentation in the Conference. All deliberations of the Symposium shall take place in English. All correspondences in respect of the Conference are to be addressed to Dr Avishek Adhikari, Secretary, IMBIC, AE 317, Salt Lake City, Sector II, Kolkata 700091, West Bengal, India; email: E-mail avishek.adh@gmail.com.
Information: http://www.imbic.org/forthcoming.html.

January 2009

* 4–6 **ACM-SIAM Symposium on Discrete Algorithms (SODA09)**, New York Marriott Downtown, New York, New York.
Description: This symposium focuses on research topics related to efficient algorithms and data structures for discrete problems. In addition to the design of such methods and structures, the scope also includes their use, performance analysis, and the mathematical problems related to their development or limitations. Performance analyses may be analytical or experimental and may address worst-case or expected-case performance. Studies can be theoretical or based on data sets that have arisen in practice and may address methodological issues involved in performance analysis.
Information: http://www.siam.org/meetings/da09/; email: wilden@siam.org.

* 5–8 **Joint Mathematics Meetings**, Washington, District of Columbia.
Information: http://www.ams.org/amsmtgs/national.html.

* 12–16 **Quantitative and Computational Aspects of Metric Geometry**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.
Overview: We have witnessed a recent revival of interest in the rich structure and profound properties of metric spaces. Much contemporary research on metric geometry is motivated by the discovery of unexpected connections linking fundamental questions in geometry and analysis with combinatorial optimization, computational complexity, and statistics. This has led to the emergence of an impressive and growing repertoire of common problems and techniques.
Organizing Committee: Subhash Khot, Bruce Kleiner, Manor Mendel, Assaf Naor, Yuval Rabani.
Application/Registration: An application/registration form is available at http://www.ipam.ucla.edu/programs/mg2009/. Applications received by December 1, 2008, will receive fullest consideration. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications. You may also simply register and attend without IPAM funding.
Information: email: sbeggs@ipam.ucla.edu; http://www.ipam.ucla.edu/programs/mg2009/.

* 12–June 26 **Algebraic Lie Theory**, Isaac Newton Institute for Mathematical Sciences, 20 Clarkson Road, Cambridge CB3 OEH, United Kingdom.
Description: Lie theory has profound connections to many areas of pure and applied mathematics and mathematical physics. In the 1950s, the original "analytic" theory was extended so that it also makes sense over arbitrary algebraically closed fields, in particular, fields of positive characteristic. Understanding fundamental objects such as Lie algebras, quantum groups, reductive groups over finite or p-adic fields and Hecke algebras of various kinds, as well as their representation theory, are the central themes of "Algebraic Lie Theory". It is anticipated that the activities of the programme will lead to a focalisation and popularisation of the various recent methods, advances and applications of Algebraic Lie Theory.
Organizers: Professor M. Geck (Aberdeen), Professor A. Kleshchev (Oregon) and Professor G. Röhrle (Ruhr-Universität Bochum).
Information: email: s.penton@newton.cam.ac.uk; http://www.newton.ac.uk/programmes/ALT/index.html.

* 14–16 **International Conference on Modeling of Engineering and Technological Problems and 9th National Conference of Indian Society of Industrial & Applied Mathematics**, BMAS Engineering College, Sharda Group, Agra, India.

Information: Details can be found at the website: http://www.bmas.edu.in and http://www.siam-india.org. Those who are interested in participating in this conference may visit the websites and contact: Prof. Abul Hasan Siddiqi, Convener, Scientific Committee, through email: Siddiqi.abulhasan@gmail.com or mobile # 00 91 9837069944.

* 19–July 3 **Discrete Integrable Systems**, Isaac Newton Institute for Mathematical Sciences, Cambridge, England.
Description: The programme will focus on a number of aspects which are likely to become of major importance for subsequent developments, such as: the connection between integrable dynamical maps and the algebraic geometry of rational surfaces, the issue of irreducibility of nonlinear special functions defined through discrete equations and the underlying Galois theory of difference equations, the underlying spectral theory and isomonodromic deformations of linear difference equations, the connection with modern developments in representation theory such as cluster algebras and affine Weyl groups, the emergence of Diophantine problems of number theory and p-adic analysis in connection with the integrability of analytic difference equations, the problem of finding symmetries and conservation laws for discrete systems, and the primary role discrete integrable systems play in quantum mechanics, in particular quantum groups and quantum field theory on the space-time lattice.
Information: email: info@newton.ac.uk; http://www.newton.ac.uk/programmes/DIS/.

* 22–30 **Numerical Approaches to Quantum Many-Body Systems**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.
Overview: The aim of this workshop is to bring together an interdisciplinary group of researchers from mathematics, physics, quantum information, computer science, and other fields to discuss advances in the computational description of quantum many-body systems. On January 22–24, we will offer a short course for young researchers with lectures and hands-on tutorials on state-of-the-art numerical techniques. The second week will feature lectures and discussions by experts in the field.
Organizing Committee: Ulrich Schollwöck, Simon Trebst, Guifre Vidal.
Application/Registration: An application/registration form is available at http://www.ipam.ucla.edu/programs/qs2009/. Applications received by December 11, 2008, will receive fullest consideration. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications. You may also simply register for the second week and attend without IPAM funding.
Information: email: sbeggs@ipam.ucla.edu; http://www.ipam.ucla.edu/programs/qs2009/.

February 2009

* 9–13 **Laplacian Eigenvalues and Eigenfunctions: Theory, Computation, Application**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.
Overview: The investigation of eigenvalues and eigenfunctions of the Laplace operator in a bounded domain or a manifold is a subject with a history of more than two hundred years, and is still a central and active area in mathematics, physics, engineering, and computer science. This workshop will be an exciting opportunity to discuss various aspects of new or long-standing problems in the field with experts in different fields, including mathematics, physics, biology, and computer sciences.
Organizing Committee: Denis Grebenkov, Peter Jones, Naoki Saito.
Application/Registration: An application/registration form is available at http://www.ipam.ucla.edu/programs/le2009/. Applications received by December 15, 2008, will receive fullest consideration. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications. You may also simply register and attend without IPAM funding.
Information: email: sbeggs@ipam.ucla.edu; http://www.ipam.ucla.edu/programs/le2009/.

* 23–27 **Modern Moduli Theory**, Mathematical Sciences Research Institute, Berkeley, California.
Organizers: I. Coskun, S. Katz, A. Marian, R. Pandharipande, R. Thomas, H. H. Tseng, R. Vakil.
Description: This workshop will convene experts specializing on the minimal model program, derived categories and moduli spaces in an informal environment to facilitate the cross-fertilization of ideas across these different fields of algebraic geometry.
Information: http://www.msri.org/calendar/workshops/WorkshopInfo/472/show_workshop.

* 23–27 **Rare Events in High-Dimensional Systems**, Institute for Pure and Applied Mathematics (IPAM), UCLA, Los Angeles, California.
Overview: It is a significant theoretical and computational challenge to quantify the rates and mechanisms of rare events. While there is a growing consensus on the open questions, it is still not clear how well current theoretical and computational techniques address them. The aim of the workshop is to address these issues through discussions with and presentations by mathematicians, chemists, physicists, and engineers.
Organizing Committee: Giovanni Ciccotti, Kristen Fichthorn, Ioannis Kevrekidis, Christof Schuette, Eric Vanden-Eijnden, Arthur Voter.
Application/Registration: An application/registration form is available at http://www.ipam.ucla.edu/programs/re2009/. Applications received by January 12, 2009 will receive fullest consideration. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications. You may also simply register and attend without IPAM funding.
Information: http://www.ipam.ucla.edu/programs/re2009/; email: sbeggs@ipam.ucla.edu.

March 2009

* 18–20 **IAENG International Conference on Scientific Computing ICSC 2009**, Regal Kowloon Hotel, Kowloon, Hong Kong.
Description: The conference ICSC'09 is held under the International MultiConference of Engineers and Computer Scientists 2009. The IMECS 2009 is organized by the International Association of Engineers (IAENG), and serves as good platforms for the engineering community members to meet with each other and to exchange ideas. The last IMECS 2008 has attracted more than one thousand participants from over 50 countries. All submitted papers will be under peer review and accepted papers will be published in the conference proceeding (ISBN: 978-988-17012-2-0). The abstracts will be indexed and available at major academic databases. The accepted papers will also be considered for publication in the special issues of the journal Engineering Letters, in IAENG journals and in edited books.
Important Dates: Draft Manuscript submission deadline: December 8, 2008. Camera-Ready Papers Due & Registration Deadline: January 10, 2009. ICCA 2009: March 18–20, 2009.
Information: http://www.iaeng.org/IMECS2009/ICSC2009.html; email: imecs@iaeng.org.

* 23–27 **Combinatorial, Enumerative and Toric Geometry**, Mathematical Sciences Research Institute, Berkeley, California.
Organizers: Michel Brion, Anders Buch, Linda Chen, William Fulton, Sándor Kovács, Frank Sottile, Harry Tamvakis, and Burt Totaro.
Description: This workshop will present the state of the art in combinatorial, enumerative, and toric algebraic geometry. It will highlight this part of modern algebraic geometry within the context of the broader semester-long parent program at MSRI, and convey its scope to young researchers.
Information: http://www.msri.org/calendar/workshops/WorkshopInfo/473/show_workshop.

* 27–29 **AMS Central Section Meeting**, University of Illinois at Urbana-Champaign, Urbana, Illinois.
Information: http://www.ams.org/amsmtgs/sectional.html.

April 2009

* 4–5 **AMS Southeastern Section Meeting**, North Carolina State University, Raleigh, North Carolina.
Information: http://www.ams.org/amsmtgs/sectional.html.

* 25–26 **AMS Eastern Section Meeting**, Worcester Polytechnic Institute, Worcester, Massachusetts.

Information: http://www.ams.org/amsmtgs/sectional.html.

* 25–26 **AMS Western Section Meeting**, San Francisco State University, San Francisco, California.
Information: http://www.ams.org/amsmtgs/sectional.html.

June 2009

* 14–20 **Stochastic Analysis and Random Dynamical Systems**, Ivan Franko National University of Lviv, Ukraine.
Description: The Conference is devoted to the modern aspects of the theory of random dynamical systems. The Conference is aimed to bring together knowledge from different fields of probability theory and stochastic processes related to this subject. The Conference will take place in Lviv, one of the oldest and most beautiful cities of Ukraine. It will be held in the building of Ivan Franko National University of Lviv. During the Conference Social and Cultural Program will be organized.
Information: http://www.imath.kiev.ua/~sard/; email: sard@imath.kiev.ua.

July 2009

* 20–24 **Equadiff 12**, Brno, Czech Republic.
Description: Under the name "Equadiff" a series of important international conferences on differential equations have been organized in Europe during the last decades. The first one took place in Prag (1962) and the second one in Bratislava (1966). From 1970 on the location alternated between Czech Republic/Slovakia and various countries of Western Europe. The most recent Equadiff conferences took place in Vienna (2007), Bratislava (2005), Hasselt (2003), Prag (2001), and Berlin (1999).
Information: email: dosly@math.muni.cz; http://www.math.muni.cz/~equadiff/.

* 20–December 18 **Non-Abelian Fundamental Groups in Arithmetic Geometry**, Isaac Newton Institute for Mathematical Sciences, Cambridge, England.
Description: In the 1980's Grothendieck formulated his anabelian conjectures that brought to an hitherto-unexplored depth the interaction between topology and arithmetic. This suggested that the study of non-abelian fundamental groups could lead to a new understanding of deep arithmetic phenomena, including the arithmetic theory of moduli and Diophantine finiteness on hyperbolic curves. A certain amount of work in recent years linking fundamental groups to Diophantine geometry intimates deep and mysterious connections to the theory of motives and Iwasawa theory, with their links with arithmetic problems on special values of L-functions such as the conjecture of Birch and Swinnerton-Dyer. The goal of this programme is to investigate the ideas and problems of anabelian geometry within the global context of mainstream arithmetic geometry.
Organisers: M. Kim (UCL), J. Coates (Cambridge), F. Pop (Pennsylvania), M. Saidi (Exeter), P. Schneider (Münster).
Information: email: info@newton.ac.uk; http://www.newton.ac.uk/programmes/NAG/.

* 29–July 24 **The Cardiac Physiome Project**, Isaac Newton Institute for Mathematical Sciences, Cambridge, England.
Description: Predicting physiological behaviour from experimental data combined with environmental influences is a compelling, but unfulfilled, goal of post-genomic biology. This undeniably ambitious goal is the aim of the Physiome Project and its subset the Cardiome Project which is an international effort to build a biophysically based multi-scale mathematical model of the heart. To achieve this goal requires further development of the current generation of advanced cardiac models which span an already diverse set of mathematical representations from stochastic sub-cellular regulation models to whole organ based sets of coupled partial differential equations. The focus of this programme will be on the development and application of the mathematical techniques which underpin the ongoing extension of this approach.
Organizers: R. H. Clayton (Sheffield); P. Hunter (Auckland); N. Smith (Oxford); S. Waters (OCIAM).
Information: email: info@newton.ac.uk; http://www.newton.ac.uk/programmes/CPP/.

The following new announcements will not be repeated until the criteria in the next to the last paragraph at the bottom of the first page of this section are met.

August 2009

* 12–December 18 **Dynamics of Discs and Planets**, Isaac Newton Institute for Mathematical Sciences, Cambridge, England.
Description: This programme will bring together world-leading researchers in disciplines including accretion disc theory, planet formation, planet-disc interaction and solar system dynamics. With such a group we seek to provide a firm theoretical basis for our understanding of extrasolar planetary systems and their formation in protoplanetary discs. The programme encompasses three themes: (1) dynamics of astrophysical discs and the numerical and analytical methods used to study them (i.e., the study of gaseous accretion discs); (2) dynamics specific to discs in which planets are forming including that formation process (i.e. the study of how solid material interacts with gaseous discs); (3) dynamics that is relevant once planets have formed (i.e. the study of solid body interactions).
Organizers: A Morbidelli (Observatoire de Nice); R. P. Nelson (Queen Mary, London); Gl. Ogilvie (Cambridge); J. M. Stone (Princeton), M. C. Wyatt (Cambridge).
Information: email: info@newton.ac.uk; http://www.newton.ac.uk/programmes/DDP/.

* 17–21 **Modular forms on noncongruence groups**, American Institute of Mathematics, Palo Alto, California.
Description: This workshop, sponsored by AIM and the NSF, will explore the arithmetic and analytic properties of noncongruence modular forms and their potential applications. A special focus will be on the connection between Scholl representations attached to noncongruence cuspforms and automorphic forms by applying modularity lifting theorems.
Information: http://aimath.org/ARCC/workshops/noncongruence.html; email: farmer@aimath.org.

October 2009

* 16–18 **AMS Central Section Meeting**, Baylor University, Waco, Texas.
Information: http://www.ams.org/amsmtgs/sectional.html.

* 24–25 **AMS Eastern Section Meeting**, Pennsylvania State University, University Park, Pennsylvania.
Information: http://www.ams.org/amsmtgs/sectional.html.

* 30–November 1 **AMS Southeastern Section Meeting**, Florida Atlantic University, Boca Raton, Florida.
Information: http://www.ams.org/amsmtgs/sectional.html.

November 2009

* 7–8 **AMS Western Section Meeting**, University of California, Riverside, California.
Information: http://www.ams.org/amsmtgs/sectional.html.

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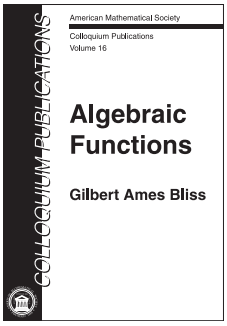
Algebra and Algebraic Geometry



Algebraic Functions

Gilbert Ames Bliss

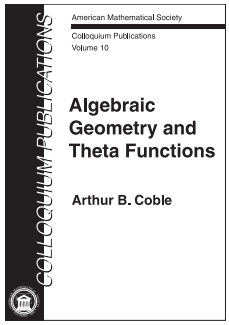
This book, immediately striking for its conciseness, is one of the most remarkable works ever produced on the subject of algebraic functions and their integrals. The distinguishing feature of the book is its third chapter, on rational functions, which gives an extremely brief and clear account of the theory of divisors.... A very readable account is given of the topology of Riemann surfaces and of the general properties of abelian integrals. Abel's theorem is presented, with some simple applications. The inversion problem is studied for the cases of genus zero and genus unity. The chapter on the reduction of singularities is very noteworthy.... A final chapter illustrates the general theory with some examples. In particular, constructive methods are given for treating algebraic relations which are of the third degree in one of the variables.... The arithmetic theory of algebraic functions is a good thing. In making its study easy, Bliss has performed a service which will win him the gratitude of an ever increasing number of readers.

—***Bulletin of the American Mathematical Society***

Contents: Single-valued analytic functions; Algebraic functions and their expansions; Rational functions; The Riemann surface of an algebraic function; Integrals of rational functions; Abel's theorem; Birational transformations; The reduction of singularities by transformation; Inversion of Abelian integrals; Examples; List of references.

Colloquium Publications, Volume 16

December 1933, 218 pages, Softcover, ISBN: 978-0-8218-4607-0, LC 34-5791, 2000 *Mathematics Subject Classification:* 14-02, **AMS members US$40**, List US$50, Order code COLL/16



Algebraic Geometry and Theta Functions

Arthur B. Coble

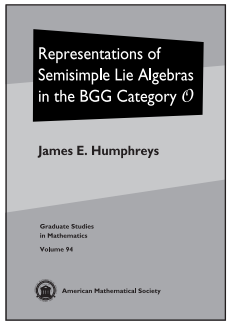
This volume is an amplification of the Colloquium Lectures delivered under the title *The Determination of the Tritangent Planes of the Space Sextic of Genus Four.* In order to present clearly the state of that problem, a comparison with the better known cases of genus two and genus three is desirable. Preliminary chapters on algebraic geometry and theta functions are incorporated in order to facilitate reading by recalling fundamental ideas of these two subjects in such fashion as will be most helpful in later applications.

This item will also be of interest to those working in number theory.

Contents: Topics in algebraic geometry; Topics in theta functions; Geometric applications of the functions of genus two; Geometric applications of the functions of genus three; Geometric aspects of the abelian modular functions of genus four; Theta relations of genus four; References.

Colloquium Publications, Volume 10

December 1929, 282 pages, Softcover, ISBN: 978-0-8218-4602-5, LC 30-12679, 2000 *Mathematics Subject Classification:* 14-XX, **AMS members US$46**, List US$58, Order code COLL/10



Representations of Semisimple Lie Algebras in the BGG Category $\mathcal{O}$

James E. Humphreys, *University of Massachusetts, Amherst, MA*

This is the first textbook treatment of work leading to the landmark 1979 Kazhdan–Lusztig Conjecture on characters of simple highest weight modules for a semisimple Lie algebra $\mathfrak{g}$ over $\mathbb{C}$. The setting is the module category $\mathcal{O}$ introduced by Bernstein–Gelfand–Gelfand, which includes all highest weight

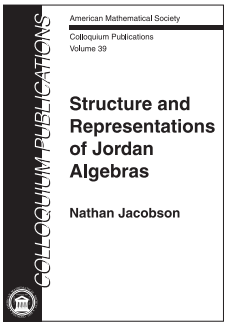
modules for $\mathfrak{g}$ such as Verma modules and finite dimensional simple modules. Analogues of this category have become influential in many areas of representation theory.

Part I can be used as a text for independent study or for a mid-level one semester graduate course; it includes exercises and examples. The main prerequisite is familiarity with the structure theory of $\mathfrak{g}$. Basic techniques in category $\mathcal{O}$ such as BGG Reciprocity and Jantzen's translation functors are developed, culminating in an overview of the proof of the Kazhdan–Lusztig Conjecture (due to Beilinson–Bernstein and Brylinski–Kashiwara). The full proof however is beyond the scope of this book, requiring deep geometric methods: D-modules and perverse sheaves on the flag variety. Part II introduces closely related topics important in current research: parabolic category $\mathcal{O}$, projective functors, tilting modules, twisting and completion functors, and Koszul duality theorem of Beilinson–Ginzburg–Soergel.

Contents: Review of semisimple Lie algebras; *Highest weight modules:* Category $\mathcal{O}$: Basics; Characters of finite dimensional modules; Category $\mathcal{O}$: Methods; Highest weight modules I; Highest weight modules II; Extensions and resolutions; Translation functors; Kazhdan-Lusztig theory; *Further developments:* Parabolic versions of category $\mathcal{O}$; Projective functors and principal series; Tilting modules; Twisting and completion functors; Complements; Bibliography; Frequently used symbols; Index.

Graduate Studies in Mathematics, Volume 94

August 2008, 289 pages, Hardcover, ISBN: 978-0-8218-4678-0, LC 2008012667, 2000 *Mathematics Subject Classification:* 17B10; 20G05, 22E47, **AMS members US$47**, List US$59, Order code GSM/94



Structure and Representations of Jordan Algebras

Nathan Jacobson

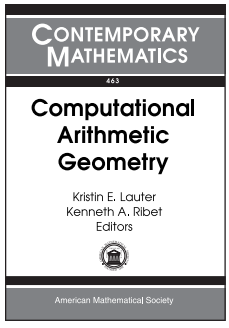
The theory of Jordan algebras has played important roles behind the scenes of several areas of mathematics. Jacobson's book has long been the definitive treatment of the subject. It covers foundational material, structure theory, and representation theory for Jordan algebras. Of course, there are immediate connections with Lie algebras, which Jacobson details in Chapter 8. Of particular continuing interest is the discussion of exceptional Jordan algebras, which serve to explain the exceptional Lie algebras and Lie groups.

Jordan algebras originally arose in the attempts by Jordan, von Neumann, and Wigner to formulate the foundations of quantum mechanics. They are still useful and important in modern mathematical physics, as well as in Lie theory, geometry, and certain areas of analysis.

Contents: Foundations; Elements of representation theory; Peirce decompositions and Jordan matrix algebras; Jordan algebras with minimum conditions on quadratic ideals; Structure theory for finite-dimensional Jordan algebras; Generic minimum polynomials, traces and norms; Representation theory for separable Jordan algebras; Connections with Lie algebras; Exceptional Jordan algebras; Further results and open questions; Bibliography; Subject index.

Colloquium Publications, Volume 39

December 1968, 453 pages, Softcover, ISBN: 978-0-8218-4640-7, LC 68-19439, 2000 *Mathematics Subject Classification:* 17-XX, 16-02, **AMS members US$66**, List US$82, Order code COLL/39.S



Computational Arithmetic Geometry

Kristin E. Lauter, *Microsoft Research, Redmond, WA*, and **Kenneth A. Ribet**, *University of California at Berkeley, CA*, Editors

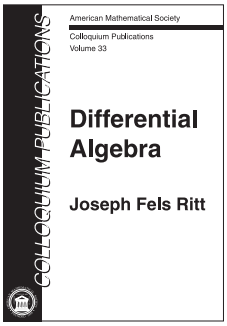
With the recent increase in available computing power, new computations are possible in many areas of arithmetic geometry. To name just a few examples, Cremona's tables of elliptic curves now go up to conductor 120,000 instead of just conductor 1,000, tables of Hilbert class fields are known for discriminant up to at least 5,000, and special values of Hilbert and Siegel modular forms can be calculated to extremely high precision. In many cases, these experimental capabilities have led to new observations and ideas for progress in the field. They have also led to natural algorithmic questions on the feasibility and efficiency of many computations, especially for the purpose of applications in cryptography. The AMS Special Session on Computational Arithmetic Geometry, held on April 29–30, 2006, in San Francisco, CA, gathered together many of the people currently working on the computational and algorithmic aspects of arithmetic geometry. This volume contains research articles related to talks given at the session. The majority of articles are devoted to various aspects of arithmetic geometry, mainly with a computational approach.

This item will also be of interest to those working in applications.

Contents: J. D. Achter, Results of Cohen-Lenstra type for quadratic function fields; **E. Bach** and **D. Charles**, The hardness of computing an eigenform; **R. Bröker** and **P. Stevenhagen**, Constructing elliptic curves of prime order; **A. Deajim** and **D. Grant**, Space-time codes and non-associative division algebras arising from elliptic curves; **J. S. Ellenberg**, Points of low height on $\mathbb{P}^1$ over number fields and bounds for torsion in class groups; **E. W. Howe**, Supersingular genus-2 curves over fields of characteristic 3; **K. S. Kedlaya**, Search techniques for root-unitary polynomials; **B. Levitt** and **W. McCallum**, Yet more elements in the Shafarevich-Tate group of the Jacobian of a Fermat curve; **K. McMurdy**, Stable reduction of $X_0(81)$; **B. Poonen**, Isomorphism types of commutative algebras of finite rank over an algebraically closed field; **R. Pries**, A short guide to p-torsion of abelian varieties in characteristic p.

Contemporary Mathematics, Volume 463

August 2008, 129 pages, Softcover, ISBN: 978-0-8218-4320-8, LC 2008010326, 2000 *Mathematics Subject Classification:* 14G05, 14G10, 14G15, 14G50, 14H45, 11G50, 11G15, 11G20, 11Y16, 11F11, **AMS members US$39**, List US$49, Order code CONM/463



Differential Algebra

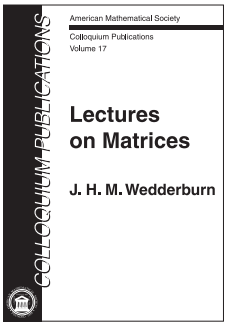
Joseph Fels Ritt

A gigantic task undertaken by J. F. Ritt and his collaborators in the 1930's was to give the classical theory of nonlinear differential equations, similar to the theory created by Emmy Noether and her school for algebraic equations and algebraic varieties. The current book presents the results of 20 years of work on this problem. The book quickly became a classic, and thus far, it remains one of the most complete and valuable accounts of differential algebra and its applications.

Contents: Differential polynomials and their ideals; Algebraic differential manifolds; Structure of differential polynomials; Systems of algebraic equations; Constructive methods; Analytical considerations; Intersections of algebraic differential manifolds; Riquier's existence theorem for orthonomic systems; Partial differential algebra; Questions for investigation; Bibliography; Index.

Colloquium Publications, Volume 33

December 1950, 184 pages, Softcover, ISBN: 978-0-8218-4638-4, LC 50-8228, **AMS members US$33**, List US$41, Order code COLL/33.S



Lectures on Matrices

J. H. M. Wedderburn

It is the organization and presentation of the material, however, which make the peculiar appeal of the book. This is no mere compendium of results—the subject has been completely reworked and the proofs recast with the skill and elegance which come only from years of devotion.

—Bulletin of the American Mathematical Society

The very clear and simple presentation gives the reader easy access to the more difficult parts of the theory.

—Jahrbuch über die Fortschritte der Mathematik

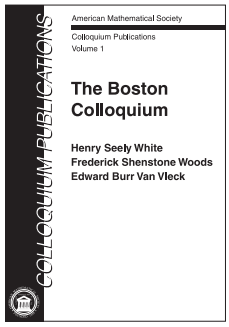
In 1937, the theory of matrices was seventy-five years old. However, many results had only recently evolved from special cases to true general theorems. With the publication of his Colloquium Lectures, Wedderburn provided one of the first great syntheses of the subject. Much of the material in the early chapters is now familiar from textbooks on linear algebra. Wedderburn discusses topics such as vectors, bases, adjoints, eigenvalues and the characteristic polynomials, up to and including the properties of Hermitian and orthogonal matrices. Later chapters bring in special results on commuting families of matrices, functions of matrices—including elements of the differential and integral calculus sometimes known as matrix analysis, and transformations of bilinear forms. The final chapter treats associative algebras, culminating with the well-known Wedderburn–Artin theorem that simple algebras are necessarily isomorphic to matrix algebras.

Wedderburn ends with an appendix of historical notes on the development of the theory of matrices, and a bibliography that emphasizes the history of the subject.

Contents: Matrices and vectors; Algebraic operations with matrices. The characteristic equation; Invariant factors and elementary divisors; Vector polynomials. Singular matric polynomials; Compound matrices; Symmetric, skew, and hermitian matrices; Commutative matrices; Functions of matrices; The automorphic transformation of a bilinear form; Linear associative algebras; Notes; Bibliography; Index to bibliography; Index.

Colloquium Publications, Volume 17

December 1934, 205 pages, Softcover, ISBN: 978-0-8218-4610-0, LC 35-4487, 2000 *Mathematics Subject Classification:* 15-02, **AMS members US$36**, List US$45, Order code COLL/17



The Boston Colloquium

Henry Seely White, Frederick Shenstone Woods, and Edward Burr Van Vleck

The 1903 colloquium of the American Mathematical Society was held as part of the summer meeting that took place in Boston. Three sets of lectures were presented: *Linear Systems of Curves on Algebraic Surfaces*, by H. S. White, *Forms of Non-Euclidean Space*, by F. S. Woods, and *Selected Topics in the Theory of Divergent Series and of Continued Fractions*, by Edward B. Van Vleck.

White's lectures are devoted to the theory of systems of curves on an algebraic surface, with particular reference to properties that are invariant under birational transformations and the kinds of surfaces that admit given systems.

Woods' lectures deal with the problem of the classification of three-dimensional Riemannian spaces of constant curvature. The author presents and discusses Riemann postulates characterizing manifolds of constant curvature, and explains in detail the results of Clifford, Klein, and Killing devoted to the local and global classification problems.

The subject of Van Vleck's lectures is the theory of divergent series. The author presents results of Poincaré, Stieltjes, E. Borel, and others about the foundations of this theory. In particular, he shows "how to determine the conditions under which a divergent series may be manipulated as the analytic representative of an unknown function, to develop the properties of the function, and to formulate methods of deriving a function uniquely from the series." In the concluding portion of these lectures, some results about continuous fractions of algebraic functions are presented.

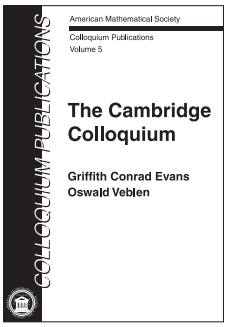
This item will also be of interest to those working in geometry and topology and analysis.

Contents: H. S. White, Linear systems of curves on algebraic surfaces; **F. S. Woods**, Forms of non-Euclidean space; **E. B. Van Vleck**, Selected topics in the theory of divergent series and of continued fractions; Bibliography.

Colloquium Publications, Volume 1

December 1905, 187 pages, Softcover, ISBN: 978-0-8218-4588-2, LC 5-19543, 2000 *Mathematics Subject Classification:* 00B15; 14Hxx, 53Axx, 40Axx, **AMS members US$35**, List US$44, Order code COLL/1

Analysis



The Cambridge Colloquium

Griffith Conrad Evans and **Oswald Veblen**

The 1916 colloquium of the American Mathematical Society was held as part of the summer meeting that took place in Boston. Two sets of lectures were presented: *Functionals and their Applications. Selected Topics, including Integral Equations*, by G. C. Evans, and *Analysis Situs*, by Oswald Veblen.

The lectures by Evans are devoted to functionals and their applications. By a *functional* the author means a function on an infinite-dimensional space, usually a space of functions, or of curves on the plane or in 3-space, etc. The first lecture deals with general considerations of functionals (continuity, derivatives, variational equations, etc.). The main topic of the second lecture is the study of complex-valued functionals, such as integrals of complex functions in several variables. The third lecture is devoted to the study of what is called implicit functional equations. This study requires, in particular, the development of the notion of a Fréchét differential, which is also discussed in this lecture. The fourth lecture contains generalizations of the Bôcher approach to the treatment of the Laplace equation, where a harmonic function is characterized as a function with no flux (Evans' terminology) through every circle on the plane. Finally, the fifth lecture gives an account of various generalizations of the theory of integral equations.

Analysis situs is the name used by Poincaré when he was creating, at the end of the 19th century, the area of mathematics known today as topology. Veblen's lectures, forming the second part of the book, contain what is probably the first text where Poincaré's results and ideas were summarized, and an attempt to systematically present this difficult new area of mathematics was made.

This is how S. Lefschetz had described, in his 1924 review of the book, the experience of "a beginner attracted by the fascinating and difficult field of analysis situs":

"Difficult reasonings beset him at every step, an unfriendly notation did not help matters, to all of which must be added, most baffling of all, the breakdown of geometric intuition precisely when most needed. No royal road can be created through this dense forest, but a good and thoroughgoing treatment of fundamentals, notation, terminology, may smooth the path somewhat. And this and much more we find supplied by Veblen's Lectures."

Of the two streams of topology existing at that time, point set topology and combinatorial topology, it is the latter to which Veblen's book is almost totally devoted. The first four chapters present, in detail, the notion and properties (introduced by Poincaré) of the incidence matrix of a cell decomposition of a manifold. The main goal of the author is to show how to reproduce main topological invariants of a manifold and their relations in terms of the incidence matrix.

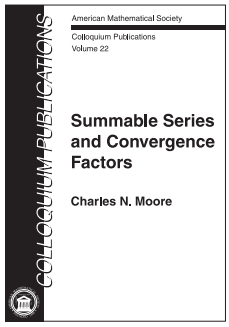
The (last) fifth chapter contains what Lefschetz called "an excellent summary of several important questions: homotopy and isotopy, theory of the indicatrix, a fairly ample treatment of the group of a manifold, finally a bird's eye view of what is known and not known (mostly the latter) on three dimensional manifolds."

This item will also be of interest to those working in geometry and topology.

Contents: G. C. Evans, Functionals and their applications. Selected topics, including integral equations; **O. Veblen**, Analysis situs.

Colloquium Publications, Volume 5

December 1918, 306 pages, Softcover, ISBN: 978-0-8218-4642-1, LC 19-12273, 2000 *Mathematics Subject Classification:* 00B15; 45-XX, 55-XX, **AMS members US$48**, List US$60, Order code COLL/5



Summable Series and Convergence Factors

Charles N. Moore

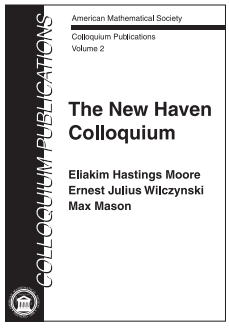
Fairly early in the development of the theory of summability of divergent series, the concept of convergence factors was recognized as of fundamental importance in the subject. One of the pioneers in this field was C. N. Moore, the author of the book under review.... Moore classifies convergence factors into two types. In type I he places the factors which have only the property that they preserve convergence for a convergent series or produce convergence for a summable series. In type II he places the factors which not only maintain or produce convergence but have the additional property that they may be used to obtain the sum or generalized sum of the series. This book gives a generalized systematic treatment of the theory of convergence factors of both types, for simply infinite series and for multiple series, convergent and summable....

—***Bulletin of the American Mathematical Society***

Contents: Introduction; Convergence factors in convergent series; Summation of series by Nörlund means; Convergence factors in summable series; Convergence factors in summable double series; Convergence factors in summable multiple series; Convergence factors in restrictedly convergent multiple series; Bibliography; Index.

Colloquium Publications, Volume 22

December 1938, 105 pages, Softcover, ISBN: 978-0-8218-4620-9, LC 38-22994, 2000 *Mathematics Subject Classification:* 40-02, **AMS members US$20**, List US$25, Order code COLL/22



The New Haven Colloquium

Eliakim Hastings Moore, Ernest Julius Wilczynski, and **Max Mason**

The American Mathematical Society held its fifth colloquium in connection with its thirteenth summer meeting, under the auspices of Yale University, during the week September 3–8, 1906. This book contains the lecture notes for the three courses that were given at this colloquium: "Introduction to a Form of General Analysis" by

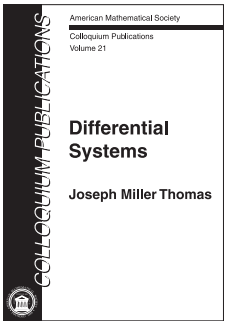
Eliakim H. Moore, "Projective Differential Geometry" by Ernest J. Wilczynski, and "Selected Topics in the Theory of Boundary Value Problems of Differential Equations" by Max Mason.

This item will also be of interest to those working in differential equations and geometry and topology.

Contents: E. H. Moore, Introduction to a form of general analysis; **E. J. Wilczyński**, Projective differential geometry; **M. Mason**, Selected topics in the theory of boundary value problems of differential equations.

Colloquium Publications, Volume 2

December 1910, 222 pages, Softcover, ISBN: 978-0-8218-4591-2, LC 10-10798, 2000 *Mathematics Subject Classification:* 26-02, 53-02, 34-02, **AMS members US$39**, List US$49, Order code COLL/2



Differential Systems

Joseph Miller Thomas

The main goal of this book is to present the theory of systems of partial differential equations and the theory of Pfaffian systems so as to exhibit clearly the relations between them.

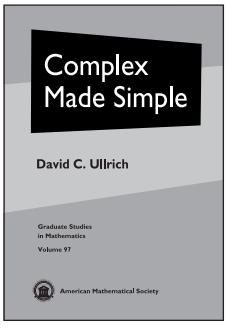
In presenting the theory of Pfaffian systems, the author develops, in detail, the theories of Grassmann algebras and rings with differentiation. In particular, following Grassmann and É. Cartan, he introduces and freely uses what is now known as a ring of differential forms with functional coefficients. In presenting the theory of systems of partial differential equations, the author concentrates on the existence of solutions and methods of approximating them, rather than on their properties. The relations and similarities of two theories are displayed through the systematic use of various versions of the elimination method.

Contents: Introduction; Generalities on symbols and systems; Grassmann algebra; Differential rings; Commutative monomials and polynomials; Algebraic systems; Algebraic differential systems; Function systems and differential systems; Pfaffian systems; Consistency examples; Illustrative examples; Bibliography; Index.

Colloquium Publications, Volume 21

December 1937, 118 pages, Softcover, ISBN: 978-0-8218-4619-3, LC 37-11417, 2000 *Mathematics Subject Classification:* 57-02; 35A10, 58A17, **AMS members US$22**, List US$28, Order code COLL/21

COURSE ADOPTION



Complex Made Simple

David C. Ullrich, *Oklahoma State University, Stillwater, OK*

Perhaps uniquely among mathematical topics, complex analysis presents the student with the opportunity to learn a thoroughly developed subject that is rich in both theory and applications. Even in an introductory course, the theorems and techniques can have elegant formulations. But for any of these profound results, the student is often left asking: What does it really mean? Where does it come from?

In *Complex Made Simple*, David Ullrich shows the student how to think like an analyst. In many cases, results are discovered or derived, with an explanation of how the students might have found the theorem on their own. Ullrich explains why a proof works. He will also, sometimes, explain why a tempting idea *does not* work.

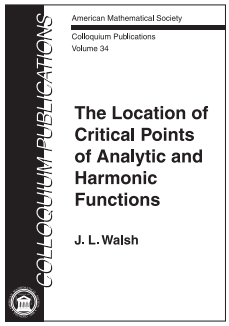
Complex Made Simple looks at the Dirichlet problem for harmonic functions twice: once using the Poisson integral for the unit disk and again in an informal section on Brownian motion, where the reader can understand intuitively how the Dirichlet problem works for general domains. Ullrich also takes considerable care to discuss the modular group, modular function, and covering maps, which become important ingredients in his modern treatment of the often-overlooked original proof of the Big Picard Theorem.

This book is suitable for a first-year course in complex analysis. The exposition is aimed directly at the students, with plenty of details included. The prerequisite is a good course in advanced calculus or undergraduate analysis.

Contents: *Part 1. Complex made simple:* Differentiability and Cauchy-Riemann equations; Power series; Preliminary results on holomorphic functions; Elementary results on holomorphic functions; Logarithms, winding numbers and Cauchy's theorem; Counting zeroes and the open mapping theorem; Euler's formula for $\sin(z)$; Inverses of holomorphic maps; Conformal mappings; Normal families and the Riemann mapping theorem; Harmonic functions; Simply connected open sets; Runge's theorem and the Mittag-Leffler theorem; The Weierstrass factorization theorem; Carathéodory's theorem; More on $\mathrm{Aut}(\mathbb{D})$; Analytic continuation; Orientation; The modular function; Preliminaries for the Picard theorems; The Picard theorems; *Part 2. Further results:* Abel's theorem; More on Brownian motion; More on the maximum modulus theorem; The Gamma function; Universal covering spaces; Cauchy's theorem for non-holomorphic functions; Harmonic conjugates; *Part 3. Appendices:* Complex numbers; Complex numbers, continued; Sin, cos and exp; Metric spaces; Convexity; Four counterexamples; The Cauchy-Riemann equations revisited; References; Index of notations; Index.

Graduate Studies in Mathematics, Volume 97

September 2008, approximately 477 pages, Hardcover, ISBN: 978-0-8218-4479-3, LC 2008017911, 2000 *Mathematics Subject Classification:* 30-01, **AMS members US$60**, List US$75, Order code GSM/97



The Location of Critical Points of Analytic and Harmonic Functions

J. L. Walsh

This book is concerned with the critical points of analytic and harmonic functions. A critical point of an analytic function means a zero of its derivative, and a critical point of a harmonic function means a point where both partial derivatives vanish. The analytic functions considered are largely polynomials, rational functions, and certain periodic, entire, and meromorphic functions. The harmonic functions considered are largely Green's functions, harmonic measures, and various linear combinations of them. The interest in these functions centers around the approximate location of their critical points. The approximation is in the sense of determining minimal regions in

which all the critical points lie or maximal regions in which no critical point lies. Throughout the book the author uses the single method of regarding the critical points as equilibrium points in fields of force due to suitable distribution of matter.

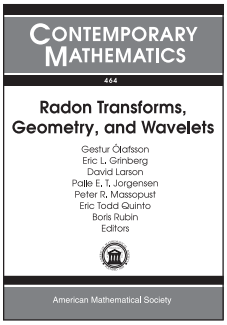
The exposition is clear, complete, and well-illustrated with many examples.

Contents: Fundamental results; Real polynomials; Polynomials, continued; Rational functions; Rational functions with symmetry; Analytic functions; Green's functions; Harmonic functions; Further harmonic functions; Bibliography; Index.

Colloquium Publications, Volume 34

December 1950, 384 pages, Softcover, ISBN: 978-0-8218-4643-8, LC 50-12177, 2000 *Mathematics Subject Classification:* 30-XX, **AMS members US$58**, List US$73, Order code COLL/34.S

Applications



Radon Transforms, Geometry, and Wavelets

Gestur Ólafsson, *Louisiana State University, Baton Rouge, LA*, **Eric L. Grinberg**, *University of New Hampshire, Durham, NH*, **David Larson**, *Texas A & M University, College Station, TX*, **Palle E. T. Jorgensen**, *University of Iowa, Iowa City, IA*, **Peter R. Massopust**, *Institute of Biomathematics and Biometry, Neuherberg, Germany*, **Eric Todd Quinto**, *Tufts University, Medford, MA*, and **Boris Rubin**, *Louisiana State University, Baton Rouge, LA*, Editors

This volume is based on two special sessions held at the AMS Annual Meeting in New Orleans in January 2007, and a satellite workshop held in Baton Rouge on January 4–5, 2007. It consists of invited expositions that together represent a broad spectrum of fields, stressing surprising interactions and connections between areas that are normally thought of as disparate. The main topics are geometry and integral transforms. On the one side are harmonic analysis, symmetric spaces, representation theory (the groups include continuous and discrete, finite and infinite, compact and non-compact), operator theory, PDE, and mathematical probability. Moving in the applied direction we encounter wavelets, fractals, and engineering topics such as frames and signal and image processing.

The subjects covered in this book form a unified whole, and they stand at the crossroads of pure and applied mathematics. The articles cover a broad range in harmonic analysis, with the main themes related to integral geometry, the Radon transform, wavelets and frame theory. These themes can loosely be grouped together as follows:

- Frame Theory and Applications
- Harmonic Analysis and Function Spaces
- Harmonic Analysis and Number Theory
- Integral Geometry and Radon Transforms
- Multiresolution Analysis, Wavelets, and Applications

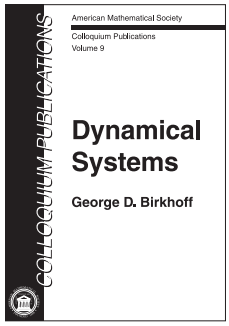
This item will also be of interest to those working in differential equations.

Contents: I. A. Aliev, **B. Rubin**, **S. Sezer**, and **S. B. Uyhan**, Composite wavelet transforms: Applications and perspectives; **J. J. Benedetto**, **O. Oktay**, and **A. Tangboondouangjit**, Complex sigma-delta quantization algorithms for finite frames; **B. Currey** and **T. McNamara**, Decomposition and admissibility for the quasiregular representation for generalized oscillator groups; **D. E. Dutkay** and **P. E. T. Jorgensen**, Fourier series on fractals: A parallel with wavelet theory; **D. V. Feldman**, A computational complexity paradigm for tomography; **F. B. Gonzalez**, Invariant differential operators on matrix motion groups and applications to the matrix radon transform; **D. Hart** and **A. Iosevich**, Sums and products in finite fields: An integral geometric viewpoint; **B. D. Johnson** and **K. A. Okoudjou**, Frame potential and finite abelian groups; **P. G. Casazza** and **G. Kutyniok**, Robustness of fusion frames under erasures of subspaces and of local frame vectors; **K. D. Merrill**, Smooth, well-localized Parseval wavelets based on wavelet sets in $\mathbb{R}^2$; **S. Jain**, **M. Papadakis**, and **E. Dussaud**, Explicit schemes in seismic migration and isotropic multiscale representations; **G. Ólafsson** and **B. Rubin**, Invariant functions on Grassmannians; **G. Ólafsson** and **S. Zheng**, Harmonic analysis related to Schrödinger operators; **I. Pesenson**, Discrete Helgason-Fourier transform for Sobolev and Besov functions on noncompact symmetric spaces; **E. T. Quinto**, Helgason's support theorem and spherical radon transforms.

Contemporary Mathematics, Volume 464

August 2008, 264 pages, Softcover, ISBN: 978-0-8218-4327-7, 2000 *Mathematics Subject Classification:* 42C40, 44A12; 43A85, 51M25, 52A22, 65T99, **AMS members US$63**, List US$79, Order code CONM/464

Differential Equations



Dynamical Systems

George D. Birkhoff

His research in dynamics constitutes the middle period of Birkhoff's scientific career, that of maturity and greatest power.

—Yearbook of the American Philosophical Society

The author's great book…is well known to all, and the diverse active modern developments in mathematics which have been inspired by this volume bear the most eloquent testimony to its quality and influence.

—Zentralblatt MATH

In 1927, G. D. Birkhoff wrote a remarkable treatise on the theory of dynamical systems that would inspire many later mathematicians to do great work. To a large extent, Birkhoff was writing about his own work on the subject, which was itself strongly influenced by Poincaré's approach to dynamical systems. With this book, Birkhoff also demonstrated that the subject was a beautiful theory, much more than a compendium of individual results. The influence of this work can be found in many fields, including differential equations, mathematical physics, and even what is now known as Morse theory.

The present volume is the revised 1966 reprinting of the book, including a new addendum, some footnotes, references added by Jürgen Moser, and a special preface by Marston Morse.

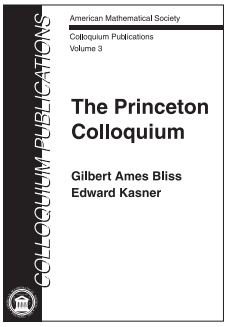
Although dynamical systems has thrived in the decades since Birkhoff's book was published, this treatise continues to offer insight and inspiration for still more generations of mathematicians.

This item will also be of interest to those working in analysis and mathematical physics.

Contents: Physical aspects of dynamical systems; Variational principles and applications; Formal aspects of dynamics; Stability of periodic motions; Existence of periodic motions; Application of Poincaré's geometric theorem; General theory of dynamical systems; The case of two degrees of freedom; The problem of three bodies; Addendum; Footnotes; Bibliography; Index.

Colloquium Publications, Volume 9

December 1927, 305 pages, Softcover, ISBN: 978-0-8218-1009-5, LC 28-28411, 2000 *Mathematics Subject Classification:* 34-XX, **AMS members US$47**, List US$59, Order code COLL/9



The Princeton Colloquium

Gilbert Ames Bliss and **Edward Kasner**

Following the early tradition of the American Mathematical Society, the sixth colloquium of the Society was held as part of the summer meeting that took place at Princeton University. Two sets of lectures were presented: *Fundamental Existence Theorems*, by G. A. Bliss, and *Geometric Aspects of Dynamics*, by Edward Kasner.

The goal of Bliss's Colloquium Lectures is an overview of contemporary existence theorems for solutions to ordinary or partial differential equations. The first part of the book, however, covers algebraic and analytic aspects of implicit functions. These become the primary tools for the existence theorems, as Bliss builds from the theories established by Cauchy and Picard. There are also applications to the calculus of variations.

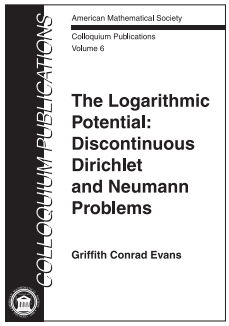
Kasner's lectures were concerned with the differential geometry of dynamics, especially kinetics. At the time of the colloquium, it was more common in kinematics to consider geometry of trajectories only in the absence of an external force. The lectures begin with a discussion of the possible trajectories in an arbitrary force field. Kasner then specializes to the study of conservative forces, including wave propagation and some curious optical phenomena. The discussion of constrained motions leads to the brachistochrone and tautochrone problems. Kasner concludes by looking at more complicated motions, such as trajectories in a resisting medium.

This item will also be of interest to those working in geometry and topology.

Contents: G. A. Bliss, Fundamental existence theorems; **E. Kasner**, Differential geometric aspects of dynamics.

Colloquium Publications, Volume 3

December 1913, 224 pages, Softcover, ISBN: 978-0-8218-4641-4, LC 14-3157, 2000 *Mathematics Subject Classification:* 34-02, 35-02, 37-02, 70-02, **AMS members US$42**, List US$52, Order code COLL/3



The Logarithmic Potential: Discontinuous Dirichlet and Neumann Problems

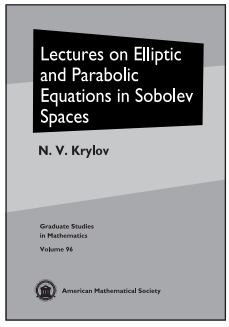
Griffith Conrad Evans

This book studies fundamental properties of the logarithmic potential and their connections to the theory of Fourier series, to potential theory, and to function theory. The material centers around a study of Poisson's integral in two dimensions and of the corresponding Stieltjes integral. The results are then extended to the integrals in terms of Green's functions for general regions. There are some thirty exercises scattered throughout the text. These are designed in part to familiarize the reader with the concepts introduced, and in part to complement the theory. The reader should know something of potential theory, functions of a complex variable, and Lebesgue integrals. The book is based on lectures given by the author in 1924–1925 at the Rice Institute and at the University of Chicago.

Contents: Preliminary concepts. Stieltjes integrals and Fourier series; Functions harmonic within a circle; Necessary and sufficient conditions. The Dirichlet problems for the circle; Potentials of a single layer and the Neumann problem; General simply connected plane regions and the order of their boundary points; Plane regions of finite connectivity; Related problems; Index.

Colloquium Publications, Volume 6

December 1927, 150 pages, Softcover, ISBN: 978-0-8218-4599-8, LC 28-28410, 2000 *Mathematics Subject Classification:* 30-02, 31-02, **AMS members US$28**, List US$35, Order code COLL/6



Lectures on Elliptic and Parabolic Equations in Sobolev Spaces

N. V. Krylov, *University of Minnesota, Minneapolis, MN*

This book concentrates on the basic facts and ideas of the modern theory of linear elliptic and parabolic equations in Sobolev spaces.

The main areas covered in this book are the first boundary-value problem for elliptic equations and the Cauchy problem for parabolic equations. In addition, other boundary-value problems such as the Neumann or oblique derivative problems are briefly covered. As is natural for a textbook, the main emphasis is on organizing well-known ideas in a self-contained exposition. Among the topics included that are not usually covered in a textbook are a relatively recent development concerning equations with VMO coefficients and the study of parabolic equations with coefficients measurable only with respect to the time variable. There are numerous exercises which help the reader better understand the material.

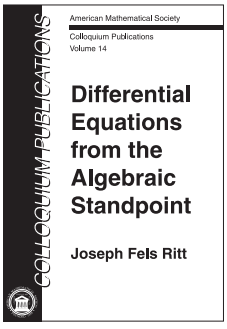
After going through the book, the reader will have a good understanding of results available in the modern theory of partial differential equations and the technique used to obtain them.

Prerequisites are basics of measure theory, the theory of L_p spaces, and the Fourier transform.

Contents: Second-order elliptic equations in $W_2^2(\mathbb{R}^d)$; Second-order parabolic equations in $W_2^{1,k}(\mathbb{R}^{d+1})$; Some tools from real analysis; Basic $\mathcal{L}_p$-estimates for parabolic and elliptic equations; Parabolic and elliptic equations in $W_p^{1,k}$ and W_p^k; Equations with VMO coefficients; Parabolic equations with VMO coefficients in spaces with mixed norms; Second-order elliptic equations in $W_p^2(\Omega)$; Second-order elliptic equations in $W_p^k(\Omega)$; Sobolev embedding theorems for $W_p^k(\Omega)$; Second-order elliptic equations $Lu - \lambda u = f$ with λ small; Fourier transform and elliptic operators; Elliptic operators and the spaces H_p^γ; Bibliography; Index.

Graduate Studies in Mathematics, Volume 96

September 2008, approximately 366 pages, Hardcover, ISBN: 978-0-8218-4684-1, LC 2008016051, 2000 *Mathematics Subject Classification:* 35-01; 35J15, 35K10, **AMS members US$52**, List US$65, Order code GSM/96



Differential Equations from the Algebraic Standpoint

Joseph Fels Ritt

This book can be viewed as a first attempt to systematically develop an algebraic theory of nonlinear differential equations, both ordinary and partial. The main goal of the author was to construct a theory of elimination, which "will reduce the existence problem for a finite or infinite system of algebraic differential equations to the application of the implicit function theorem taken with Cauchy's theorem in the ordinary case and Riquier's in the partial." In his 1934 review of the book, J. M. Thomas called it "concise, readable, original, precise, and stimulating", and his words still remain true.

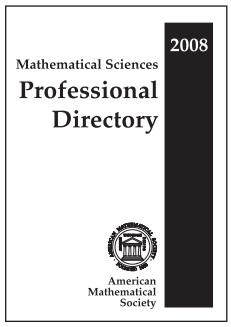
A more fundamental and complete account of further developments of the algebraic approach to differential equations is given in Ritt's treatise *Differential Algebra*, written almost 20 years after the present work (Colloquium Publications, Vol. 33, American Mathematical Society, 1950).

Contents: Decomposition of a system of ordinary algebraic differential equations into irreducible systems; General solutions and resolvents; First applications of the general theory; Systems of algebraic equations; Constructive methods; Constitution of an irreducible manifold; Analogue of the Hilbert–Netto theorem. Theoretical decomposition process; Analogue for form quotients of Lüroth's theorem; Riquier's existence theorem for orthonomic systems; Systems of algebraic partial differential equations; Index.

Colloquium Publications, Volume 14

December 1932, 172 pages, Softcover, ISBN: 978-0-8218-4605-6, LC 32-35201, 2000 *Mathematics Subject Classification:* 12-02; 12H05, **AMS members US$32**, List US$40, Order code COLL/14

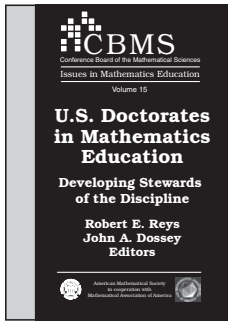
General and Interdisciplinary



Mathematical Sciences Professional Directory, 2008

This annual directory provides a handy reference to various organizations in the mathematical sciences community. Listed in the directory are the following: contact (address, phone, fax) info and websites of over thirty professional mathematical organizations; addresses of selected government agencies; academic departments in the mathematical sciences; and alphabetic listings of colleges and universities.

July 2008, 153 pages, Softcover, ISBN: 978-0-8218-4451-9, List US$55, Institutional member US$44, Order code PRODIR/2008



U.S. Doctorates in Mathematics Education

Developing Stewards of the Discipline

Robert E. Reys, *University of Missouri, Columbia, MO*, and **John A. Dossey**, *Illinois State University, Eureka, IL*, Editors

Mathematics education in the United States will be shaped at all levels by those who hold doctorates in the field. As professors, they influence the structure and content of university programs in mathematics education, where future teachers are prepared. As scholars, they engage in research and lead us to a deeper and better understanding of the field. This book is a detailed study of doctoral programs in mathematics education. It stems from a national conference sponsored by the National Science Foundation. It involved participants from across the United States, as well as Brazil, Japan, Norway, and Spain, and followed up the work of an earlier conference, published in *One Field, Many Paths: U.S. Doctoral Programs in Mathematics Education* (Volume 9 in this series).

The book, as was the conference, is organized around several major questions, including: What is the core knowledge for doctoral students in mathematics education? What are the important issues and challenges in delivering doctoral programs? What can we learn about doctoral preparation by comparisons with other countries? What effect would accreditation of doctoral programs in mathematics education have on the profession? What next steps need to be addressed now?

The book documents the wide range of ideas about doctoral programs in mathematics education and their varied features. It provides readers with current visions and issues concerning doctoral studies in the field and serves as a reminder that establishing stewards of the discipline of mathematics education is a continuing challenge.

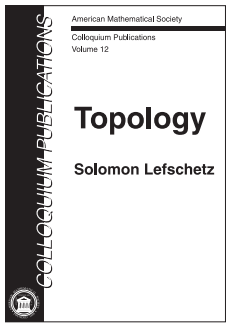
This series is published in cooperation with the Mathematical Association of America.

Contents: *Part 1: Background:* **R. Reys**, **R. Glasgow**, **D. Teuscher**, and **N. Nevels**, Doctoral production in mathematics education in the United States: 1960–2005; **R. Reys**, **R. Glasgow**, **D. Teuscher**, and **N. Nevels**, Doctoral programs in mathematics education in the United States: 2007 status report; **D. Teuscher**, **N. Nevels**, and **C. Ulrich**, Report of a 2007 survey of U. S. doctoral students in mathematics education; *Part 2: Developing stewards of the discipline: core elements:* **C. M. Golde**, Creating a broader vision of doctoral education: Lessons from the Carnegie Initiative on the Doctorate; **J. Ferrini-Mundy**, What core knowledge do doctoral students in mathematics education need to know?; *Breakout sessions:* **D. Chazan** and **W. J. Lewis**, The mathematical education of doctorates in mathematics education; **R. M. Zbiek** and **C. R. Hirsch**, Curriculum as core knowledge; **E. Silver** and **E. Walker**, Making policy issues visible in the doctoral preparation of mathematics educators; **P. S. Wilson** and **M. Franke**, Preparing teachers in mathematics education doctoral programs: Tensions and strategies; **E. V. Taylor** and **R. Kitchen**, Doctoral programs in mathematics education: Diversity and equity; **M. K. Heid** and **H. S. Lee**, Using technology in teaching and learning mathematics: What should doctoral students in mathematics education know?; *Part 3: Developing stewards of the discipline: delivery systems:* **D. S. Mewborn**, Program delivery issues, opportunities, and challenges; *Breakout sessions:* **J. A. Middleton** and **B. Dougherty**, Doctoral preparation of researchers; **W. S. Bush** and **E. Galindo**, Key components of mathematics education doctoral programs in the United States: Current practices and suggestions for improvement; **M. Burke** and **V. M. Long**, On-line delivery graduate courses in mathematics education; **G. Kersaint** and **G. A. Goldin**, Mathematics education doctoral programs: Approaches to part-time students; **B. J. Reys**, **G. M. Lloyd**, **K. Marrongelle**, and **M. S. Winsor**, Induction of doctoral graduates in mathematics education into the profession; *Part 4: Doctoral programs in mathematics education: Some international perspectives:* **J. Kilpatrick**, Doctoral programs in mathematics education: An international perspective; **B. S. D'ambrosio**, Doctoral studies in mathematics education: Unique features of Brazilian programs; **B. Grevholm**, Nordic doctoral programs in didactics of mathematics; **M. Koyama**, Japanese doctoral programs in mathematics education: Academic or professional; **L. Rico**, **A. Fernández-Cano**, **E. Castro**, and **M. Torralbo**, Post-graduate study program in mathematics education at the University of Granada (Spain); *Part 5: Accreditation:* **G. Lappan**, **J. Newton**, and **D. Teuscher**, Accreditation of doctoral programs: A lack of consensus; *Part 6: Reflections from within:* **A. Tyminski**, Preparing the next generation of mathematics educators: An assistant professor's experience; **D. Kirshner** and **T. Ricks**, Mathematics content for elementary mathematics education graduate students: Overcoming the prerequisites hurdle; **D. Teuscher**, **A. M. Marshall**, **J. Newton**, and **C. Ulrich**, Intellectual communities: Promoting collaboration within and across doctoral programs in mathematics education; *Part 7: Closing commentary:* **J. Hiebert**, **D. Lambdin**, and **S. Williams**, Reflecting on the conference and looking toward the future; Appendices.

CBMS Issues in Mathematics Education, Volume 15

July 2008, 271 pages, Softcover, ISBN: 978-0-8218-4584-4, LC 2008017013, 2000 *Mathematics Subject Classification:* 97-XX, 00-XX, **AMS members US$44**, List US$55, Order code CBMATH/15

Geometry and Topology



Topology

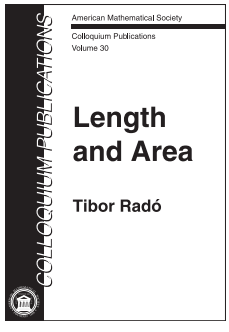
Solomon Lefschetz

Lefschetz's *Topology* was written in the period in between the beginning of topology, by Poincaré, and the establishment of algebraic topology as a well-formed subject, separate from point-set or geometric topology. At this time, Lefschetz had already proved his first fixed-point theorems. In some sense, the present book is a description of the broad subject of topology into which Lefschetz's theory of fixed points fits. Lefschetz takes the opportunity to describe some of the important applications of his theory, particularly in algebraic geometry, to problems such as counting intersections of algebraic varieties. He also gives applications to vector distributions, complex spaces, and Kronecker's characteristic theory.

Contents: Elementary combinatorial theory of complexes; Topological invariance of the homology characters; Manifolds and their duality theorems; Intersections of chains on a manifold; Product complexes; Transformations of manifolds, their coincidences and fixed points; Infinite complexes and their applications; Applications to analytical and algebraic varieties; Bibliography; Addenda; Index.

Colloquium Publications, Volume 12

December 1930, 413 pages, Softcover, ISBN: 978-0-8218-4603-2, LC 31-10604, 2000 *Mathematics Subject Classification:* 54-02, 55-02, **AMS members US$61**, List US$76, Order code COLL/12



Length and Area

Tibor Radó

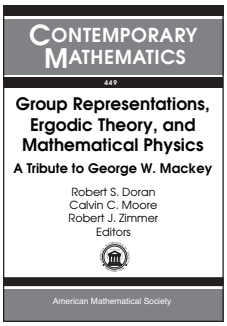
Radó's colloquium is a systematic treatment of Lebesgue theory, with an emphasis on the work of Morrey and of Radó and his students, especially in two dimensions. At the time, there were important current problems surrounding Lebesgue's theory for parameterized and unparameterized surfaces, which the book addresses. The exposition begins with reviews of Lebesgue integration and relevant topics in topology, including Fréchet equivalence, the approximation of monotone maps by homeomorphisms, Peano spaces, and a discussion of the topological index of maps into the plane. After a development of further ideas and tools from topology and measure theory, Radó addresses an essential question that equates two sorts of areas for surfaces represented by maps of a 2-cell or a 2-sphere into 3-space.

Contents: Background material; Curves and surfaces; Arc length and related topics; Plane tranformations; Surface area; Bibliography; Index.

Colloquium Publications, Volume 30

December 1948, 572 pages, Softcover, ISBN: 978-0-8218-4621-6, LC 48-3259, 2000 *Mathematics Subject Classification:* 28-02, **AMS members US$79**, List US$99, Order code COLL/30

Mathematical Physics



Group Representations, Ergodic Theory, and Mathematical Physics

A Tribute to George W. Mackey

Robert S. Doran, *Texas Christian University, Fort Worth, TX*, **Calvin C. Moore**, *University of California, Berkeley, CA*, and **Robert J. Zimmer**, *University of Chicago, IL*, Editors

George Mackey was an extraordinary mathematician of great power and vision. His profound contributions to representation theory, harmonic analysis, ergodic theory, and mathematical physics left a rich legacy for researchers that continues today. This book is based on lectures presented at an AMS special session held in January 2007 in New Orleans dedicated to his memory. The papers, written especially for this volume by internationally known mathematicians and mathematical physicists, range from expository and historical surveys to original high-level research articles. The influence of Mackey's fundamental ideas is apparent throughout. The introductory article contains recollections from former students, friends, colleagues, and family as well as a biography describing his distinguished career as a mathematician at Harvard, where he held the Landon D. Clay Professorship of Mathematics.

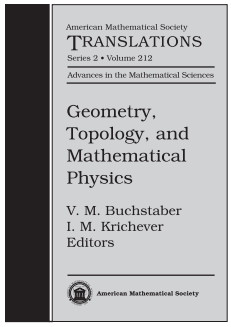
Topics examined here include recent results on induced representations, virtual groups, the Mackey Machine and crossed products, representations of Baumslag-Solitar groups, the Radon transform and the heat equation, groupoids in the study of wavelets, and quantum theory. The in-depth historical surveys of Mackey's work on representation theory, ergodic theory, and physics, together with recent developments inspired by his fundamental work will be of considerable interest to both graduate students and researchers alike.

This item will also be of interest to those working in general and interdisciplinary areas.

Contents: R. S. Doran and **A. Ramsay**, George Mackey 1916–2006; **S. Adams**, Decay to zero of matrix coefficients at adjoint infinity; **J. Arthur**, Induced representations, intertwining operators and transfer; **L. G. Brown**, MASA's and certain type I closed faces of C^*-algebras; **D. E. Dutkay** and **P. E. T. Jorgensen**, A duality approach to representations of Baumslag-Solitar groups; **S. Echterhoff** and **D. P. Williams**, The Mackey machine for crossed products: Inducing primitive ideals; **E. G. Effros**, Classifying the unclassifiables; **N. Higson**, The Mackey analogy and K-theory; **R. E. Howe**, Some recent applications of induced representations; **M. Ionescu** and **P. S. Muhly**, Groupoid methods in wavelet analysis; **A. Jaffe**, Quantum theory and relativity; **A. A. Kirillov**, Thoughts about George Mackey and his imprimitivity theorem; **C. C. Moore**, Virtual groups 45 years later; **F. Murnaghan**, Spherical characters: The supercuspidal case; **G. Ólafsson** and **H. Schlichtkrull**, Representation theory, radon transform and the heat equation on a Riemannian symmetric space; **J. A. Packer**, Projective representations and the Mackey obstruction—A survey; **A. Ramsay**, Virtual groups for group representations; **M. A. Rieffel**, A global view of equivariant vector bundles and Dirac operators on some compact homogeneous spaces; **V. S. Varadarajan**, George Mackey and his work on representation theory and foundations of physics.

Contemporary Mathematics, Volume 449

January 2008, 446 pages, Softcover, ISBN: 978-0-8218-4225-6, LC 2007060574, 2000 *Mathematics Subject Classification:* 22D10, 22D30, 22E50, 28A05, 43A07, 46L05, 58J60, 81-02, 81P10, 81T08, **AMS members US$95**, List US$119, Order code CONM/449



Geometry, Topology, and Mathematical Physics

S. P. Novikov's Seminar: 2006–2007

V. M. Buchstaber, *Steklov Institute of Mathematics, Moscow, Russia*, and **I. M. Krichever**, *Columbia University, New York, NY*, Editors

This volume contains a selection of papers based on presentations given in 2006–2007 at the S. P. Novikov Seminar at the Steklov Mathematical Institute in Moscow. Novikov's diverse interests are reflected in the topics presented in the book. The articles address topics in geometry, topology, and mathematical physics. The volume is suitable for graduate students and researchers interested in the corresponding areas of mathematics and physics.

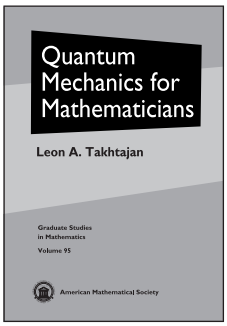
This item will also be of interest to those working in geometry and topology.

Contents: A. V. Alexeevski and **S. M. Natanzon**, Hurwitz numbers for regular coverings of surfaces by seamed surfaces and Cardy-Frobenius algebras of finite groups; **V. M. Buchstaber** and **S. Terzić**, Equivariant complex structures on homogeneous spaces and their cobordism classes; **B. Dubrovin**, On universality of critical behaviour in Hamiltonian PDEs; **M. Feigin** and **A. P. Veselov**, On the geometry of $\vee$-systems; **P. G. Grinevich** and **I. A. Taimanov**, Spectral conservation laws for periodic nonlinear equations of the Melnikov type; **S. M. Gusein-Zade**, **I. Luengo**, and **A. Melle-Hernández**, An equivariant version of the monodromy zeta function; **A. Hamilton** and **A. Lazarev**, Symplectic $\mathcal{A}_\infty$-algebras and string topology operations; **H. M. Khudaverdian** and **T. T. Voronov**, Differential forms and odd symplectic geometry; **I. Krichever** and **T. Shiota**, Abelian solutions of the KP equation; **A. Y. Maltsev**, Deformations of the Whitham systems in the almost linear case; **O. I. Mokhov**, Frobenius manifolds as a special class of submanifolds in pseudo-Euclidean spaces; **M. V. Pavlov**, Integrability of the Gibbons-Tsarev system; **A. K. Pogrebkov**, 2D toda chain and associated commutator identity; **O. K. Sheinman**, On certain current algebras related to finite-zone integration.

American Mathematical Society Translations—Series 2 (*Advances in the Mathematical Sciences*), Volume 224

September 2008, approximately 285 pages, Hardcover, ISBN: 978-0-8218-4674-2, LC 91-640741, 2000 *Mathematics Subject Classification:* 00B25, **AMS members US$87**, List US$109, Order code TRANS2/224

COURSE ADOPTION



Quantum Mechanics for Mathematicians

Leon A. Takhtajan, *Stony Brook University, NY*

This book provides a comprehensive treatment of quantum mechanics from a mathematics perspective and is accessible to mathematicians starting with second-year graduate students. In addition to traditional topics, like classical mechanics, mathematical foundations of quantum mechanics, quantization, and the Schrödinger equation, this book gives a mathematical treatment of systems of identical particles with spin, and it introduces the reader to functional methods in quantum mechanics. This includes the Feynman path integral approach to quantum mechanics, integration in functional spaces, the relation between Feynman and Wiener integrals, Gaussian integration and regularized determinants of differential operators, fermion systems and integration over anticommuting (Grassmann) variables, supersymmetry and localization in loop spaces, and supersymmetric derivation of the Atiyah-Singer formula for the index of the Dirac operator. Prior to this book, mathematicians could find these topics only in physics textbooks and in specialized literature.

This book is written in a concise style with careful attention to precise mathematics formulation of methods and results. Numerous problems, from routine to advanced, help the reader to master the subject. In addition to providing a fundamental knowledge of quantum mechanics, this book could also serve as a bridge for studying more advanced topics in quantum physics, among them quantum field theory.

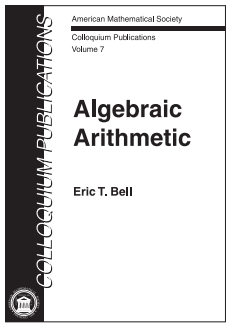
Prerequisites include standard first-year graduate courses covering linear and abstract algebra, topology and geometry, and real and complex analysis.

Contents: *Foundations:* Classical mechanics; Basic principles of quantum mechanics; Schrödinger equation; Spin and identical particles; *Functional methods and supersymmetry:* Path integral formulation of quantum mechanics; Integration in functional spaces; Fermion systems; Supersymmetry; Bibliography; Index.

Graduate Studies in Mathematics, Volume 95

September 2008, approximately 389 pages, Hardcover, ISBN: 978-0-8218-4630-8, LC 2008013072, 2000 *Mathematics Subject Classification:* 81-01, **AMS members US$55**, List US$69, Order code GSM/95

Number Theory



Algebraic Arithmetic

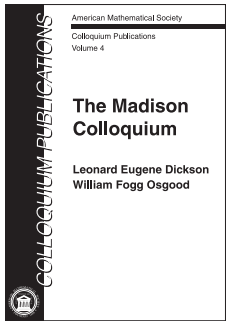
Eric T. Bell

The central topic of this book is the presentation of the author's principle of arithmetical paraphrases, which won him the Bôcher Prize in 1924. This general principle served to unify and extend many isolated results in the theory of numbers. The author successfully provides a systematic attempt to find a unified theory for each of various classes of related important problems in the theory of numbers, including its interrelations with algebra and analysis. This book will be of interest to advanced students in various branches of mathematics, including number theory, abstract algebra, elliptic and theta functions, Bernoulli numbers and functions, and the foundations of mathematics.

Contents: Introduction; Varieties of algebra useful in algebraic arithmetic; The algebra $\mathcal{B}$ of parity; The algebraic arithmetic of multiply periodic functions; Applications of the algebras $\mathcal{C}$, $\mathcal{D}$; Arithmetical structure; Index.

Colloquium Publications, Volume 7

December 1927, 180 pages, Softcover, ISBN: 978-0-8218-4601-8, LC 28-28412, 2000 *Mathematics Subject Classification:* 11-02, **AMS members US$33**, List US$41, Order code COLL/7



The Madison Colloquium

Leonard Eugene Dickson and **William Fogg Osgood**

Following the tradition of the American Mathematical Society, the seventh colloquium of the Society was held as part of the summer meeting that took place at the University of Wisconsin, in Madison. Two sets of lectures were presented: *On Invariants and the Theory of Numbers*, by L. E. Dickson, and *Functions of Several Complex Variables*, by W. F. Osgood.

Dickson considers invariants of quadratic forms, with a special emphasis on invariants of forms defined in characteristic p, also called modular invariants, which have number-theoretic consequences. He is able to find a fundamental set of invariants for both settings. For binary forms, Dickson introduces semi-invariants in the modular case, and again finds a fundamental set. These studies naturally lead to the important study of invariants of the standard action of the modular group. The lectures conclude with a study of "modular geometry", which is now known as geometry over $\mathbf{F}_p$.

The lectures by Osgood review the state of the art of several complex variables. At this time, the theory was entirely function-theoretic. Already, though, Osgood can introduce the ideas and theorems that will be fundamental to the subject for the rest of the century: Weierstrass preparation, periodic functions and theta functions,

singularities—including Hartogs' phenomenon, the boundary of a domain of holomorphy, and so on.

This item will also be of interest to those working in analysis.

Contents: L. E. Dickson, On invariants and the theory of numbers; **W. F. Osgood**, Topics in the theory of functions of several complex variables.

Colloquium Publications, Volume 4

December 1914, 230 pages, Softcover, ISBN: 978-0-8218-4598-1, LC 14-11712, 2000 *Mathematics Subject Classification:* 11-02, 32-02, **AMS members US$42**, List US$52, Order code COLL/4

New AMS-Distributed Publications

Number Theory

Diophantine Equations

N. Saradha, *Tata Institute of Fundamental Research, Mumbai, India, Editor*

The study of Diophantine equations has a long and rich history, getting its impetus with the advent of Baker's theory of linear forms in logarithms, in the 1960's. T. N. Shorey's contribution to Diophantine equations, based on Baker's theory, is widely acclaimed. An international conference was held at the Tata Institute of Fundamental Research, Mumbai from December 16–20 2005, in his honor. This volume has evolved out of the papers contributed by several participants and non-participants of the conference. These articles reflect the various aspects of exponential Diophantine equations from experts in the field.

A publication of the Tata Institute of Fundamental Research. Distributed worldwide except in India, Bangladesh, Bhutan, Maldavis, Nepal, Pakistan, and Sri Lanka.

Contents: S. D. Adhikari, **S. Baier**, and **P. Rath**, An extremal problem in lattice point combinatorics; **G. K. Bakshi**, **M. Raka**, and **A. Sharma**, Existence of polyadic codes in terms of Diophantine equations; **R. Balasubramanian** and **K. Ramachandra**, Some problems of analytic number theory—V; **M. A. Bennett**, Powers from five terms in arithmetic progression; **Y. Bugeaud**, Linear forms in the logarithms of algebraic numbers close to 1 and applications to Diophantine equations; **S. David** and **N. Hirata-Kohno**, Logarithmic functions and formal groups of elliptic curves; **M. Filaseta**, **C. Finch**, and **J. R. Leidy**, T. N. Shorey's influence in the theory of irreducible polynomials; **K. Győry** and **A. Pinter**, Polynomial powers and a common generalization of binomial Thue-Mahler equations and S-unit equations; **M. Kulkarni** and **B. Sury**, On the Diophantine Equation $1 + x + \frac{x^2}{2!} + \cdots + \frac{x^n}{n!} = g(y)$; **F. Luca** and **A. Togbé**, On numbers of the form $\pm x^2 \pm y!$; **M. Mignotte**, Linear forms in two and three logarithms and interpolation determinants; **Y. V. Nesterenko**, Algebraic independence in the p-adic domain; **P. Philippon**, Remark on p-adic algebraic independence theory; **M. R. Murty** and **V. K. Murty**, On a conjecture of Shorey; **N. Saradha** and **A. Srinivasan**, Generalized Lebesgue-Ramanujan-Nagell equations; **A. Schinzel**, Around Pólya's theorem on the set of prime divisors of a linear recurrence; **W. M. Schmidt**, The number of solutions of some Diophantine equations; **C. L. Stewart**, On the greatest square free factor of terms of a linear recurrence sequence; **D. S. Thakur**, Diophantine approximation and transcendence in finite characteristic; **R. J. Tijdeman**, On irrationality and transcendency of infinite sums of rational numbers; **M. Waldschmidt**, The role of complex conjugation in transcendental number theory.

Tata Institute of Fundamental Research

December 2007, 300 pages, Hardcover, ISBN: 978-81-7319-898-4, 2000 *Mathematics Subject Classification:* 11D41, 45-XX, 57-XX, 11J81, 11M06, 82-XX, 85-XX, 86-XX, **AMS members US$24**, List US$30, Order code TIFR/12

AMS Policy for Employment Advertisements

While the American Mathematical Society (AMS) does not screen ads for compliance, the Society expects all institutions posting advertisements in AMS publications to comply with the equal opportunity laws that apply in the jurisdictions in which they are located. Federal law prohibits employers in the United States from discriminating on the basis of race, color, national origin, religion, sex, age or disability. Applicants should be aware that institutions outside of the United States may not be legally bound to conform to these or similar requirements, and are advised to inform themselves of conditions that may exist at the institutions to which they apply. The AMS reserves the right to reject any advertisement.

The AMS strongly supports equal opportunity in employment. Despite increasing participation at many levels, low rates of retention and promotion of women and underrepresented minorities remain a serious concern, particularly at doctoral-granting institutions. Therefore, AMS members, both individual and institutional, are urged to examine frequently their policies and procedures to see in what ways they may facilitate careers in mathematics research for women and underrepresented minorities. Resources can be found at the website: **http://www.ams.org/employment/equalopportunity.html**

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AMERICAN MATHEMATICAL SOCIETY
www.ams.org

Classified Advertisements

Positions available, items for sale, services available, and more

ILLINOIS

ILLINOIS WESLEYAN UNIVERSITY
Department of Mathematics
Tenure-Track Assistant Professor of Mathematics

The Department of Mathematics and Computer Science at Illinois Wesleyan University invites applications for a tenure-track assistant professor of mathematics. Employment will begin in August 2009, and the teaching load will be six courses per year. All candidates must have a Ph.D. in mathematics with a specialization in number theory. Candidates are expected to have completed their Ph.D. by August 1, 2009.

Applicants for the position should submit by mail a letter of application, curriculum vitae, AMS Standard Cover Sheet, and a research and teaching statement, and have three letters of recommendation sent separately to: Mathematics Search Committee, Department of Mathematics and Computer Science, Illinois Wesleyan University, P.O. Box 2900, Bloomington, IL 61702-2900. Electronic applications are not normally accepted. Applications completed after November 1, 2008, may not receive full consideration. For further information, see `http://www2.iwu.edu/iwujobs/`.

Illinois Wesleyan is an Equal Opportunity Employer committed to a diverse work force.

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KUWAIT

KUWAIT UNIVERSITY
Faculty of Science Kuwait

The Department of Mathematics and Computer Science in the Faculty of Science at Kuwait University invites applications for appointment of faculty members starting from September 2008, for the academic year 2008/2009, in one of the following areas:

Financial Mathematics, Dynamical Systems, Graph Theory, Optimization, Mathematical Modeling, Analysis, Functional Analysis, Complex Analysis, Differential Equations, Computational Mathematics.

Required Qualifications:

* Ph.D. degree in the area of specialization from a reputable university. * The applicant's GPA in first university degree should be 3 points out of 4 (or equivalent). * Research experience and significant publications in refereed international journals. * Full command of teaching in English. * Minimum of 5 years in university teaching experience in the specified field. * The successful candidates are expected to have a strong commitment and dedication to quality teaching and research.

Benefits include attractive tax-free salary according to rank and teaching experience (Professor's monthly salary varies from 2,950 to 3,192 KD., Associate Prof.'s salary varies from KD. 2,265 to 2,507, Assistant Professor's monthly salary varies from KD. 1,830 to 2,070—[KD.1 = US$3.40]); annual air tickets for the faculty member and his/her family (spouse and up to three children under the age of 20);a one time settling-in allowance; housing allowance; free national health medical care; paid mid-term holidays and summer vacations; and end-of-contract gratuity. The university also offers an excellent academic environment and financial support for research projects.

To apply, send by express mail/courier service or email, within two weeks of the date of announcement, a completed application form, updated curriculum vitae (including mailing address, phone and fax numbers, email address, academic qualifications, teaching and research experience, and a list of publications in professional journals up to 10 reprints), three copies of Ph.D., Masters, and Bachelor certificates and transcripts (an English translation of all documents in other languages should be enclosed), a copy of the passport, three recommendation letters, and names and addresses of three persons well-acquainted with the academic and professional work of the applicant. Please use PDF format for all electronic application materials. Applications and inquiries should be addressed to:

Dr. Salem Al-Yakoob
Chairman
Department of Mathematics and Computer Science
Faculty of Science, Kuwait University
P.O. Box 5969, Safat, 13060, Kuwait;
tel: (965) 4813129;
fax: +965 4817201;
email: `math@sci.kuniv.edu.kw`;
`http://www.sci.kuniv.edu.kw`

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Suggested uses for classified advertising are positions available, books or lecture notes for sale, books being sought, exchange or rental of houses, and typing services.

The 2007 rate is $110 per inch or fraction thereof on a single column (one-inch minimum), calculated from top of headline. Any fractional text of 1/2 inch or more will be charged at the next inch rate. No discounts for multiple ads or the same ad in consecutive issues. For an additional $10 charge, announcements can be placed anonymously. Correspondence will be forwarded.

Advertisements in the "Positions Available" classified section will be set with a minimum one-line headline, consisting of the institution name above body copy, unless additional headline copy is specified by the advertiser. Headlines will be centered in boldface at no extra charge. Ads will appear in the language in which they are submitted.

There are no member discounts for classified ads. Dictation over the telephone will not be accepted for classified ads.

Upcoming deadlines for classified advertising are as follows: September 2008 issue–June 30, 2008; October 2008 issue–July 29, 2008; November 2008 issue–August 28, 2008; December 2008 issue–October 1, 2008; January 2009 issue–October 28, 2008; February 2009–November 26, 2008.

U.S. laws prohibit discrimination in employment on the basis of color, age, sex, race, religion, or national origin. "Positions Available" advertisements from institutions outside the U.S. cannot be published unless they are accompanied by a statement that the institution does not discriminate on these grounds whether or not it is subject to U.S. laws. Details and specific wording may be found on page 1373 (vol. 44).

Situations wanted advertisements from involuntarily unemployed mathematicians are accepted under certain conditions for free publication. Call toll-free 800-321-4AMS (321-4267) in the U.S. and Canada or 401-455-4084 worldwide for further information.

Submission: Promotions Department, AMS, P.O. Box 6248, Providence, Rhode Island 02940; or via fax: 401-331-3842; or send email to `classads@ams.org`. AMS location for express delivery packages is 201 Charles Street, Providence, Rhode Island 20904. Advertisers will be billed upon publication.

Meetings & Conferences of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the *Notices.* However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on the AMS website. See `http://www.ams.org/meetings/`. Final programs for Sectional Meetings will be archived on the AMS website accessible from the stated URL and in an electronic issue of the *Notices* as noted below for each meeting.

Vancouver, Canada

University of British Columbia and the Pacific Institute of Mathematical Sciences (PIMS)

October 4–5, 2008

Saturday – Sunday

Meeting #1041

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: August 2008
Program first available on AMS website: August 21, 2008
Program issue of electronic *Notices*: October 2008
Issue of *Abstracts*: Volume 29, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: August 12, 2008

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Freeman Dyson, Institute for Advanced Study, *Birds and Frogs* (Einstein Public Lecture in Mathematics).

Richard Kenyon, Brown University, *Branched polymers in two and three dimensions.*

Alexander S. Kleshchev, University of Oregon, *Representation theory of symmetric groups.*

Mark Lewis, University of Alberta, *Title to be announced.*

Audrey A. Terras, University of California San Diego, *Ihara zeta functions and quantum chaos.*

Special Sessions

Algebraic Topology and Related Topics (Code: SS 3A), **Alejandro Adem**, University of British Columbia, and **Stephen Ames Mitchell**, University of Washington.

Algorithmic Probability and Combinatorics (Code: SS 15A), **Manuel Lladser**, University of Colorado, **Robert S. Maier**, University of Arizona, **Marni Mishna**, Simon Fraser University, and **Andrew Rechnitzer**, University of British Columbia.

Applications of Algebraic Geometry (Code: SS 14A), **Elizabeth S. Allman**, University of Alaska Fairbanks, and **Rekha R. Thomas**, University of Washington.

Combinatorial Representation Theory (Code: SS 1A), **Sara C. Billey**, University of Washington, **Alexander S. Kleshchev**, University of Oregon, and **Stephanie Jane Van Willigenburg**, University of British Columbia.

Convex and Discrete Geometry and Asymptotic Analysis (Code: SS 17A), **Karoly Bezdek**, University of Calgary, and **A. E. Litvak**, University of Alberta.

Harmonic Analysis and Related Topics (Code: SS 12A), **Malabika Pramanik**, University of British Columbia, and **Burak Erdogan**, University of Illinois at Urbana-Champaign.

Hilbert Functions and Free Resolutions (Code: SS 4A), **Susan Cooper**, California Polytechnic State University, **Christopher A. Francisco**, Oklahoma State University, and **Benjamin P. Richert**, California Polytechnic State University.

History and Philosophy of Mathematics (Code: SS 11A), **Shawnee L. McMurran**, California State University San Bernardino, and **James J. Tattersall**, Providence College.

Knotting and Linking of Macromolecules (Code: SS 18A), **Eric J. Rawdon**, University of Saint Thomas, and **Kenneth C. Millett**, University of California Santa Barbara.

Moduli Spaces and Singularity Theory (Code: SS 8A), **James B. Carrell**, **Patrick Brosnan**, and **Kalle Karu**, University of British Columbia.

Noncommutative Algebra and Geometry (Code: SS 6A), **Jason Bell**, Simon Fraser University, and **James Zhang**, University of Washington.

Noncommutative Geometry (Code: SS 13A), **Raphael Ponge**, University of Toronto, **Bahram Rangipour**, University of New Brunswick, and **Heath Emerson**, University of Victoria.

Nonlinear Waves and Coherent Structures (Code: SS 16A), **Bernard Deconinck**, University of Washington, and **Jeffrey DiFranco**, Seattle University.

Probability and Statistical Mechanics (Code: SS 7A), **David Brydges**, University of British Columbia, and **Richard Kenyon**, Brown University.

Special Functions and Orthogonal Polynomials (Code: SS 2A), **Mizanur Rahman**, Carleton University, and **Diego Dominici**, State University of New York New Paltz.

Wavelets, Fractals, Tilings and Spectral Measures (Code: SS 5A), **Dorin Ervin Dutkay**, University of Central Florida, **Palle E. T. Jorgensen**, University of Iowa, and **Ozgur Yilmaz**, University of British Columbia.

West End Number Theory (Code: SS 9A), **Nils Bruin**, Simon Fraser University, **Matilde N. Lalin**, University of Alberta, and **Greg Martin**, University of British Columbia.

p-adic Groups and Automorphic Forms (Code: SS 19A), **Clifton L. R. Cunningham**, University of Calgary, and **Julia Gordon**, University of British Columbia.

Accommodations

Participants should make their own arrangements directly with the properties listed below. Special rates for the meeting are available at the properties shown below for the period of October 2-6. When making reservations **participants should state that they are a guest of the American Mathematical Society or AMS**. The AMS is not responsible for rate changes or for the quality of the accommodations. Hotels have varying cancellation or early checkout penalties; be sure to ask for details when making your reservation}. Please note that all prices are in Canadian dollars (CAD) and do not include taxes.

West Coast Suites, 5959 Student Union Blvd, Vancouver, BC V6T 2C9; 604-882-1000 or toll-free: 888-822-1030 or make reservations online at: https://reserve.ubcconferences.com/pls/wss/html_ui_search.availability?ref=12345&ses=&cha=GROU P&grp=G81002A&arr=10/02/2008&dep=10/06/2008&pro=UBC; CAD$139 per night, single/double. The West Coast Suites are located directly on campus and within walking distance to the meeting. Rooms feature natural wood and stone materials, king bed in the bedroom and double sofa in the living room, wireless high-speed Internet, and LCD television. Conveniently located on campus at Campus Suites http://www.ubcconferences.com/travel_information_maps/directions/. **Deadline for reservations is September 2, 2008**.

Park Inn & Suites Vancouver Broadway, 898 West Broadway, Vancouver, BC, V5Z 1J8; 604-872-8661, fax: 604-872-2270, or toll-free 800-663-5403; rates start at CAD$89 single/double. Complimentary high-speed wireless Internet, bottle of water and newspaper as well as local and 800# calls. All rooms have a balcony. Please visit http://www.parking.com/vancouverca. **Deadline for reservations is August 18, 2008**.

Holiday Inn Vancouver Center, 711 West Broadway, Vancouver, BC, V5Z 3Y2; 604-707-1939; Rates start at CAD$139 per night, single/double. For further information please visit http://www.ichotelsgroup.com/h/d/hi/1/en/hotel/yvrbw?_requestid=309598. **Deadline for reservations is September 3, 2008**.

Food Service

The UBC food services website lists all available on-campus restaurants: http://www.food.ubc.ca/campusdining/locations/index.html.

Local Information

Please visit the following sites: Pacific Institute for the Mathematical Sciences (PIMS) at http://www.pims.math.ca/ and UBC Mathematics Department at http://www.math.ubc.ca/. A comprehensive local guide can also be found at: http://www.pims.math.ca/~kleung/07local_guide.doc. Visit the Vancouver Tourist info centre at 200 Burrard Street or at http://www.tourismvancouver.com or call 800-663-6000.

There are two useful campus maps: UBC Wayfinder (Web version of campus map with search engine) http://www.maps.ubc.ca/PROD/index.php and a UBC campus map (hardcopy version) http://www.maps.ubc.ca/PROD/images/pdf/ubcmap.pdf.

Other Activities

AMS Book Sale: Stop by the on-site AMS Bookstore—review the newest titles from the AMS, enter the FREE book drawing, enjoy up to 25% off all AMS publications or take home an AMS T-shirt! Complimentary coffee will be served courtesy of AMS Membership Services.

AMS Editorial Activity: An acquisitions editor from the AMS book program will be present to speak with prospective authors. If you have a book project that you would like to discuss with the AMS, please stop by the book exhibit.

Einstein Public Lecture in Mathematics: Freeman Dyson, Institute for Advanced Study, *Birds and Frogs,* 6:00 p.m., Saturday, October 4, Woodward (Instructional Resources Centre-IRC), Room 2. http://www.students.ubc.ca/facultystaff/buildings.cfm?code=WOOD.

Social Event

PIMS will host a reception following the Einstein lecture at 7:15 p.m. in the Pacific Spirit Place located in the Student Union Building, Main Floor, 6138 Student Union Boulevard.

Parking

UBC Parking info can be found at http://www.parking.ubc.ca/visitor.html. Participants are strongly encouraged to park at the Parkades located on campus. The rate on weekends is a flat rate of CAD$4.

Registration and Meeting Information

The registration desk and book exhibit will be located in the South Concourse display area in the Student Union Building, 6138 Student Union Boulevard, http://www.maps.ubc.ca/PROD/index_detail.php?locat1=790. The desk will be open Saturday, October 4, from 7:30 a.m. until 4:00 p.m. and Sunday, October 5, from 7:30 a.m. until noon. Fees are CAD/US$40 for AMS or Canadian Mathematical Society (CMS) members, CAD/US$60 for nonmembers; and CAD/US$5 for students/unemployed/emeritus, payable on site by cash (either CAD$ or US$), check or credit card.

The **Invited Addresses** are in the Biological Sciences Building, BIOL 2000, http://www.students.ubc.ca/facultystaff/buildings.cfm?code=BIOL.

The **Special sessions and Contributed Paper Session** are in the following buildings:

Chemical and Biological Engineering Building, http://www.students.ubc.ca/facultystaff/buildings.cfm?code=CHBE.

Biological Sciences Building, http://www.students.ubc.ca/facultystaff/buildings.cfm?code=BIOL.

Chemistry Building, http://www.students.ubc.ca/facultystaff/buildings.cfm?code=CHML.

Hugh Dempster Pavilion, http://www.students.ubc.ca/facultystaff/buildings.cfm?code=DMP.

Forest Sciences Centre, http://www.students.ubc.ca/facultystaff/buildings.cfm?code=FSC.

Transportation

The nearest major commercial airport is the Vancouver International Airport. The airport is located approximately 9.5 miles from UBC. Travel time to the campus is approximately 25 minutes. Please visit Google Maps for comprehensive directions to or from UBC.

Driving From Vancouver International Airport: Head south on Grant McConachie Way. Take the Granville Street-City Centre exit. Turn left at West 70th Avenue. West 70th Avenue becomes SW Marine Drive; follow SW Marine Drive for approximately 10 km (6 miles). Turn right onto 16th Avenue. Turn left onto Wesbrook Mall; follow Wesbrook Mall through two sets of lights and turn left at Student Union Boulevard.

Driving from Seattle: Take Interstate 5 North to the Canadian border. Continue north for 40 minutes on Highway 99. Highway 99 turns into Oak Street at the Oak Street Bridge, 6 km north of the George Massey Tunnel. Continue across the bridge on Oak Street and turn left onto West 49th Avenue. Continue along West 49th until it joins SW Marine Drive. Turn right onto 16th Avenue. Turn left onto Wesbrook Mall; follow Wesbrook Mall through two sets of lights and turn left at Student Union Boulevard.

Driving from Downtown Vancouver: Turn right onto 4th Avenue West from either Granville or Burrard Street. Follow 4th Ave. westbound for approximately 5 km (3 miles). 4th Avenue turns into Chancellor Boulevard. Turn left onto Wesbrook Mall and right onto Student Union Boulevard.

Taxi: The Vancouver International Airport is 15 km (9.5 miles) from the UBC Campus. Taxi fare is metered and is approximately CAD$35 one way.

Car rental: Special rates have been negotiated with **Avis Rent A Car** for the period September 26 to October 12, 2008, beginning at CAD$25/day for a subcompact car at the weekend rate (the weekend rate is available from noon Thursday until midnight Monday) All rates include unlimited free mileage. Rates do not include state or local surcharges, tax, optional coverages, or gas refueling charges. Renter must meet Avis' age, driver, and credit requirements, and return to the same renting location. Make reservations by calling 800-331-1600 or online at http://www.avis.com. Please quote **Avis Discount Number JO98887** when making reservations.

Weather

The fall season in Vancouver (September–October) is comfortable, with moderate temperatures (43-56 degree Fahrenheit) and occasional rain.

Information for International Participants

Entry into Canada is solely determined by Canadian Border Services Agency (CBSA) officials in accordance with Canadian law, see http://www.cbsa.gc.ca for details. Canadian law requires that all persons entering Canada must carry both proof of citizenship and identity. A valid U.S. passport or NEXUS card satisfies these requirements for U.S. citizens. If U.S. citizen travelers to Canada do not have a passport or approved alternate document such as a NEXUS card, they must show a government-issued photo ID (e.g., driver's license) and proof of U.S. citizenship such as a U.S. birth certificate, naturalization certificate, or expired U.S. passport. Children under sixteen need only present proof of U.S. citizenship.

U.S. citizens entering Canada from a third country must have a valid U.S. passport. A visa is not required for U.S. citizens to visit Canada for up to 180 days. Anyone seeking to enter Canada for any purpose besides a visit (e.g., to work, study, or immigrate) must qualify for the appropriate entry status, and should contact the Canadian Embassy or nearest consulate and see the Canadian immigration website at http://www.cic.gc.ca/english/index.asp. Anyone with a criminal record (including even misdemeanors or Driving While Impaired (DWI)) charges may be barred from entering Canada and must qualify for a special waiver well in advance of any planned travel for further processing, which may take some time.

For further information on entry requirements, travelers may contact the Canadian Embassy at 501 Pennsylvania Avenue NW, Washington DC 20001, telephone 202-682-1740, or the Canadian consulates in Atlanta, Boston, Buffalo, Chicago, Dallas, Detroit, Los Angeles, Miami, Minneapolis, New York, San Juan, or Seattle. The Canadian Embassy's web site is http://www.canadianembassy.org/.

Middletown, Connecticut

Wesleyan University

October 11–12, 2008
Saturday – Sunday

Meeting #1042
Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: August 2008
Program first available on AMS website: August 28, 2008
Program issue of electronic *Notices*: October 2008
Issue of *Abstracts*: Volume 29, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: August 19, 2008

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Pekka Koskela, University of Jyväskylän, *Title to be announced.*

Monika Ludwig, Polytechnic University New York, *Title to be announced.*

Duong Hong Phong, Columbia University, *Title to be announced.*

Thomas W. Scanlon, University of California, Berkeley, *Title to be announced.*

Special Sessions

Algebraic Geometry (Code: SS 1A), **Eyal Markman** and **Jenia Tevelev**, University of Massachusetts, Amherst.

Algebraic Topology (Code: SS 10A), **Mark A. Hovey**, Wesleyan University, and **Kathryn Lesh**, Union College.

Analysis on Metric Measure Spaces and on Fractals (Code: SS 15A), **Piotr Hajlasz**, University of Pittsburgh, **Luke Rogers**, University of Connecticut, **Robert S. Strichartz**, Cornell University, and **Alexander Teplyaev**, University of Connecticut.

Complex Geometry and Partial Differential Equations (Code: SS 3A), **Jacob Sturm** and **Jian Song**, Rutgers University.

Computability Theory and Effective Algebra (Code: SS 14A), **Joseph S. Miller**, **David Reed Solomon**, and **Asher Kach**, University of Connecticut.

Convex and Integral Geometry (Code: SS 16A), **Monika Ludwig**, Polytechnic University of New York, **Daniel Klain**, University of Massachusetts, Lowell, and **Franz Schuster**, Vienna University of Technology.

Difference Equations and Applications (Code: SS 8A), **Michael A. Radin**, Rochester Institute of Technology.

Geometric Function Theory and Geometry (Code: SS 5A), **Petra Bonfert-Taylor**, Wesleyan University, **Katsuhiko Matsuzaki**, Okayama University, and **Edward C. Taylor**, Wesleyan University.

Geometric Group Theory and Topology (Code: SS 6A), **Matthew Horak**, University of Wisconsin-Stout, **Melanie Stein**, Trinity College, and **Jennifer Taback**, Bowdoin College.

History of Mathematics (Code: SS 11A), **Robert E. Bradley**, Adelphi University, **Lawrence A. D'Antonio**, Ramapo College of New Jersey, and **Lee J. Stemkoski**, Adelphi University.

Low-Dimensional Topology (Code: SS 13A), **Constance Leidy**, Wesleyan University, and **Shelly Harvey**, Rice University.

Model Theory and Its Applications (Code: SS 12A), **Thomas Scanlon**, University of California, Berkeley, and **Philip A. Scowcroft** and **Carol S. Wood**, Wesleyan University.

Number Theory (Code: SS 4A), **Wai Kiu Chan** and **David Pollack**, Wesleyan University.

Real and Complex Dynamics of Rational Difference Equations with Applications (Code: SS 7A), **Mustafa Kulenovic** and **Gerasimos Ladas**, University of Rhode Island.

Riemannian and Lorentzian Geometries (Code: SS 2A), **Ramesh Sharma**, University of New Haven, and **Philippe Rukimbira**, Florida International University.

Accommodations

Participants should make their own arrangements directly with a hotel of their choice as early as possible. Special rates have been negotiated with the hotels listed below. The AMS is not responsible for rate changes or for the quality of the accommodations. When making a reservation, **participants should state that they are with the Wesleyan University Department of Mathematics Meeting**. Cancellation and early checkout penalties vary with each hotel; be sure to check the policy when you make your reservations.

N.B. The number of rooms available at these prices in these hotels is limited! Participants are encouraged to **book a hotel room early** as rooms may sell out.

The Inn at Middletown, Middletown, 70 Main Street, Middletown, CT 06457; 860-854-6300, toll free 800-637-9851; fax: 860-854-6301; `http://www.innatmiddletown.com/`. The hotel is approximately 7/10 of a mile walking distance of the meeting site; US$125 for single/double. Rates quoted **do not** include the sales and occupancy tax of 12%. Amenities include a full-service restaurant, as well as a lounge on the premises, Internet access in sleeping room at no charge, free wireless access in the lobby and heated indoor pool/spa. Self-parking is complimentary although valet parking is US$6 and US$12 overnight. **Deadline for reservations is September 10, 2008**. Be sure to check cancellation and early checkout policies. You will find there are a number of restaurants within walking distance.

The Courtyard by Marriott, Cromwell, 4 Sebethe Drive, Cromwell, Connecticut 06416; 860-635-1001; fax: 860-635-0684; `http://www.marriott.com/hotels/travel/bdlhc-courtyard-hartford-cromwell/`. The

hotel is approximately six miles, about (a 15–20 minute drive) to the meeting site; US$99 for single/double. Rates quoted **do not** include the sales and occupancy tax of 12%. Be sure to check cancellation and early checkout policies. Amenities include a restaurant which serves breakfast and dinner, lounge, swimming pool, fitness center, 24-hour business center, wireless Internet in public areas, complimentary lobby computer, Starbuck's, and complimentary on-site parking. **Deadline for reservations is September 10, 2008**.

Comfort Inn in Cromwell, 111 Berlin Rd., Cromwell, Connecticut, 06416; 860-635-4100; fax: 860 632-9546; http://www.comfortinn.com/ires/en-US/html/HotelInfo?hotel=CT032&promo=gglocal. The hotel is an approximate 10-minute drive to the meeting site; US$79.99 single/double. Rates quoted **do not** include the sales and occupancy tax of 12%. Be sure to check cancellation and early checkout policies. Amenities include complimentary high speed access in all rooms, free continental breakfast (6–10 a.m.), and complimentary parking. **Deadline for reservations is September 10, 2008**.

The Marriott Rocky Hill, 100 Capital Boulevard, Rocky Hill, Connecticut, 06067; 860-257-6000; toll-free: 800-228-9290; fax: 860-257-6060; http://www.marriott.com/hotels/fact-sheet/travel/bdlrh-hartford-marriott-rocky-hill/. The hotel is approximately less than a 9-mile, 20-minute drive to the campus meeting site; US$139 for single. Rates quoted **do not** include the sales and occupancy tax of 12%. Be sure to check cancellation and early checkout policies. Amenities include complimentary wireless in public areas and high-speed in sleeping room, swimming pool, fitness center, and complimentary on-site parking. There is a restaurant on site which serves breakfast, lunch and dinner. **Deadline for reservations is September 10, 2008**.

Residence Inn by Marriott, 680 Cromwell Avenue, Rocky Hill, Connecticut, 06067; (**rate program code: AMSS**) telephone: 860-257-7500; fax: 860-529-6952; http://www.marriott.com/hotels/travel/bdlrr-residence-inn-hartford-rocky-hill/ the hotel is less than a 9-mile, 15-minute drive to the campus meeting site; US$129.95 per room for one-bedroom suites and US$199.95 per room for two-bedroom suites. Rates quoted **do not** include the sales and occupancy tax of 12%. Be sure to check cancellation and early checkout policies. Amenities include complimentary breakfast buffet served 7:00–10:00 a.m., complimentary wireless in lobby and complimentary high-speed Internet access in sleeping rooms, indoor pool, and whirlpool, 24/7 fitness center and complimentary on-site parking. **Deadline for reservations is September 10, 2008**.

Food Service

On campus: the Usdan Campus Center is open all day Saturday and Sunday. The PI cafe in the Exley Science Tower is open from 1:00 p.m. to 6:00 p.m. Saturday and Sunday. There is also a cafe in the campus bookstore, Broad Street Books, 45 Broad St.

Within walking distance one can find a variety of choices for an informal meal. Details at http://www.wesleyan.edu/about/restaurants.html; additional information and recommendations will be provided on site.

Local Information

The Wesleyan University visitor's guide can be found at http://www.wesleyan.edu/about/.

Other Activities

AMS Book Sale: Stop by the on-site AMS Bookstore—review the newest titles from the AMS, enter the FREE book drawing, enjoy up to 25% off all AMS publications or take home an AMS T-shirt! Complimentary coffee will be served courtesy of AMS Membership Services.

AMS Editorial Activity: An acquisitions editor from the AMS book program will be present to speak with prospective authors. If you have a book project that you would like to discuss with the AMS, please stop by the book exhibit.

Parking

All campus lots are available for parking on the weekend; there is no fee for parking. The lot behind Exley is small; there are larger parking lots nearby, one at the corner of Lawn and High Street, and another on Pine Street a block south of campus. There is also on-street parking south of Exley, e.g., on Lawn, Brainard, Pine, and Home Streets.

Registration and Meeting Information

The meeting will be held in the Exley Science Center, Wesleyan University, Middletown, CT. Meeting registration, Exhibits and the Invited Addresses will all take place in Exley. Fees are US$40 for AMS or CMS members; US$60/nonmembers; and US$5 students, unemployed mathematicians, and emeritus members. Fees are payable on site by cash, check, or credit card. Sessions will be held in both Exley (Bldg. #34 on the campus map) and in the Public Affairs Center (Bldg #66). See the map at http://www.wesleyan.edu/about/campusmap.html.

Travel and Campus Information (as of April 2008 and subject to change)

Wesleyan campus map at http://www.wesleyan.edu/about/campusmap.html.

Car Rental: Avis is the official car rental company for the sectional meeting in Middletown, CT. All rates include unlimited free mileage. Weekend daily rates are effective from noon Thursday, October 8, 2008, to 11:59 p.m. Monday, October 13, 2008, and rates start at US$30 per day. Should a lower qualifying rate become available at the time of booking, Avis is pleased to offer a 5% discount off the lower qualifying rate or the meeting rate, whichever is lowest. Rates do not include any state or local surcharges, tax, optional coverages or gas refueling charges. Renters must meet Avis' age, driver, and credit requirements. Reservations can be made by calling 1-800-331-1600 or online at http://www.avis.com and use the **Avis Meeting Discount Number J098887**.

All the major car rental companies can be found at the airport.

By Air: Bradley International Airport (BDL) is physically located in Windsor Locks, Connecticut, and is the closest airport to the Wesleyan University campus (approximately 32 miles and about a 40-minute drive). Taxi fare from the airport is about US$75. All the major car rental companies can be found at the airport.

By Train: The closest AMTRAK (800-872-7245) station is in Meriden, CT (7 miles from Middletown). Amtrak (http://www.amtrak.com) arrives and departs from Meriden train station (7 miles from campus). However, Union Station, in New Haven, CT, is a larger train station with more service than the Meriden station. It offers service from New York's Grand Central Metronorth 800-638-7646 as well as from AMTRAK from Boston and New York's Penn Station. Taxi fare from the New Haven train station is about US$75. There is an Avis rental office at the New Haven train station.

By Bus: Both Greyhound Bus Lines, 800-229-9424, http://www.greyhound.com, and Peter Pan Bus Lines, 800-343-9999, http://www.peterpanbus.com, serve the campus.

Driving directions:

From Hartford and points north: Take I-91 south to Exit 22 for Route 9 southbound. At exit 15, turn right onto Route 66 West (Washington Street), turn left onto High Street.

From New Haven, New York, and points south: Take I-95 North to I-91 North. At exit 18, take Route 691/66 East. Route 66 becomes Washington Street in Middletown. Take right onto High Street. Or, take I-95 north to the Merritt/Wilbur Cross Parkway (Route 15 North) to Route 66 Eastbound. Take right onto High Street.

From Waterbury and points west: Take I-84 East. Take exit 27 to Route 691/66 East. Route 66 becomes Washington Street in Middletown. Take right onto High Street.

From Boston and points northeast: Take the Massachusetts Turnpike (I-90) West to Exit 9 for I-84 West to Hartford. Take exit 57 over the Charter Oak Bridge and follow the signs to I-91 South. Take I-91 south to exit 22 for Route 9 Southbound, At exit 15, turn right onto Route 66 West (Washington Street), turn left onto High Street. Or, take I-95 South through Providence, then take Exit 69 to Route 9 North (approximately 26 miles to Middletown). At exit 15, turn left.

Information for International Participants

Visa regulations are continually changing for travel to the United States. Visa applications may take from three to four months to process and require a personal interview, as well as specific personal information. International participants should view the important information about traveling to the U.S. found at http://www7.nationalacademies.org/visas/Traveling_to_US.html and http://travel.state.gov/visa/index.html. If you need a preliminary conference invitation in order to secure a visa, please send your request to dls@ams.org.

If you discover you do need a visa, the National Academies website (see above) provides these tips for successful visa applications:

* Visa applicants are expected to provide evidence that they are intending to return to their country of residence. Therefore, applicants should provide proof of "binding" or sufficient ties to their home country or permanent residence abroad. This may include documentation of the following:
- family ties in home country or country of legal permanent residence
- property ownership
- bank accounts
- employment contract or statement from employer stating that the position will continue when the employee returns;

* Visa applications are more likely to be successful if done in a visitor's home country than in a third country;

* Applicants should present their entire trip itinerary, including travel to any countries other than the United States, at the time of their visa application;

* Include a letter of invitation from the meeting organizer or the U.S. host, specifying the subject, location and dates of the activity, and how travel and local expenses will be covered;

* If travel plans will depend on early approval of the visa application, specify this at the time of the application;

* Provide proof of professional scientific and/or educational status (students should provide a university transcript).

This list is not to be considered complete. Please visit the web sites above for the most up-to-date information.

Weather

In this region of Connecticut, the averages for the month of October are normally mild at approximately 59° F and lows of 40° F. Precipitation in October averages 3 inches and snow is not expected (but you never know!). New England weather varies considerably. It would be wise to consult the weather forecast on the web (e.g. http://www.wunderground.com/cgi-bin/findweather/getForecast?query=06459 or http://www.weather.com).

Kalamazoo, Michigan

Western Michigan University

October 17–19, 2008

Friday – Sunday

Meeting #1043

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: August 2008
Program first available on AMS website: September 4, 2008
Program issue of electronic *Notices*: October 2008
Issue of *Abstracts*: Volume 29, Issue 4

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: Expired
For abstracts: August 26, 2008

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

M. Carme Calderer, University of Minnesota, *Title to be announced*.

Alexandru Ionescu, University of Wisconsin, *Title to be announced*.

Boris S. Mordukhovich, Wayne State University, *Title to be announced*.

David Nadler, Northwestern University, *Title to be announced*.

Special Sessions

Affine Algebraic Geometry (Code: SS 9A), **Shreeram Abhyankar**, Purdue University, **Anthony J. Crachiola**, Saginaw Valley State University, and **Leonid G. Makar-Limanov**, Wayne State University.

Computation in Modular Representation Theory and Cohomology (Code: SS 2A), **Christopher P. Bendel**, University of Wisconsin-Stout, **Terrell L. Hodge**, Western Michigan University, **Brian J. Parshall**, University of Virginia, and **Cornelius Pillen**, University of South Alabama.

Computational Group Theory (Code: SS 13A), **Luise-Charlotte Kappe**, State University of New York Binghamton, **Arturo Magidin**, University of Louisiana–Lafayette, and **Robert F. Morse**, University of Evansville.

Graph Labeling, Graph Coloring, and Topological Graph Theory (Code: SS 5A), **Arthur T. White**, Western Michigan University, and **David L. Craft**, Muskingum College.

Homotopy Theory (Code: SS 8A), **Michele Intermont**, Kalamazoo College, and **John R. Martino** and **Jeffrey A. Strom**, Western Michigan University.

Linear Codes Over Rings and Modules (Code: SS 11A), **Steven T. Dougherty**, University of Scranton, and **Jay A. Wood**, Western Michigan University.

Mathematical Finance (Code: SS 3A), **Qiji J. Zhu**, Western Michigan University, and **George Yin**, Wayne State University.

Mathematical Knowledge for Teaching (Code: SS 7A), **Kate Kline** and **Christine Browning**, Western Michigan University.

Nonlinear Analysis and Applications (Code: SS 1A), **S. P. Singh**, University of Western Ontario, **Bruce B. Watson**, Memorial University, and **Mahi Singh**, University of Western Ontario.

Optimization/Midwest Optimization Seminar (Code: SS 6A), **Jay S. Treiman** and **Yuri Ledyaev**, Western Michigan University, and **Ilya Shvartsman**, Penn State Harrisburg.

Quasigroups, Loops, and Nonassociative Division Algebras (Code: SS 14A), **Clifton E. Ealy Jr.** and **David Richter**, Western Michigan University, and **Petr Vojtechovsky**, University of Denver.

Representations of Real and P-adic Lie Groups (Code: SS 10A), **Alessandra Pantano**, University of California Irvine, **Annegret Paul**, Western Michigan University, and **Susana Alicia Salamanca-Riba**, New Mexico State University.

Topological Field Theory (Code: SS 12A), **David Nadler**, Northwestern University.

Variational Analysis and its Applications (Code: SS 4A), **Yuri Ledyaev** and **Jay S. Treiman**, Western Michigan University, **Ilya Shvartsman**, Penn State Harrisburg, and **Qiji J. Zhu**, Western Michigan University.

Accommodations

Participants should make their own arrangements directly with a hotel of their choice as early as possible. Special rates (rates do not include any applicable taxes) have been negotiated with the hotels listed below. The AMS is not responsible for rate changes or for the quality of the accommodations. When making a reservation, **participants should state that they are with the AMS Meeting Group**. Cancellation and early checkout penalties may apply; be sure to check the policy when you make your reservations. **Room rates are based on availability. Participants are encouraged to make reservations early.**

Radisson Plaza Hotel & Suites, 100 W Michigan Avenue, Kalamazoo, MI 49007; 269-343-3333; http://www.radisson.com/kalamazoomi. AMS meeting rate: US$135 standard room, space available basis, complimentary airport shuttle. The distance to Fetzer Center: 2 miles.

Holiday Inn West, 2747 S. 11th St, Kalamazoo, MI 49009; 269-375-6000; http://www.kalamazooholidayinn.com. AMS meeting rate: US$119 Fri/Sat, US$99 other nights, standard room, space available basis, complimentary airport shuttle. The distance to Fetzer Center: 3.5 miles.

Comfort Inn, 739 W Michigan Avenue, Kalamazoo, MI 49007; 269-384-2800; http://www.comfortinn.com. AMS meeting rate: US$104, standard room, space available basis. The distance to Fetzer Center: 1.5 miles.

Baymont Inn & Suites, 2203 S 11th St, Kalamazoo, MI 49009; 269-372-7999; http://www.baymontinns.com. AMS meeting rate: US$55, standard room, space available basis. The distance to Fetzer Center: 3 miles.

Food Service

The Fetzer Center will offer a la carte breakfast and lunch items during the day on Saturday. There will be a variety of hot and cold selections including beverages. Sunday morning, breakfast muffins, coffee, and juices will be available. The Fetzer Center accepts cash only as payment.

The WMU Student Center (Bernhard Center) is a short walk from the Fetzer Center, and offers a variety of dining options, open weekends. Visit http://www.wmich.edu/bernhard for Bernhard Center restaurants and hours of operation.

Further information regarding dining options in Kalamazoo can be found online at http://www.discoverkalamazoo.com/images/diningguide2008.pdf.

Local Information

For further information please consult the websites maintained by Western Michigan University: http://wmich.

edu and the department of mathematics at http://www.wmich.edu/math. A detailed printable campus map can be found at: http://maps.pp.wmich.edu/KaMai/ and http://www.wmich.edu/fetzer/location/map_wmu.html.

Other Activities

AMS Book Sale: Stop by the on-site AMS Bookstore—review the newest titles from the AMS, enter the FREE book drawing, enjoy up to 25% off all AMS publications or take home an AMS T-shirt! Complimentary coffee will be served courtesy of AMS Membership Services.

AMS Editorial Activity: An acquisitions editor from the AMS book program will be present to speak with prospective authors. If you have a book project that you would like to discuss with the AMS, please stop by the book exhibit.

Social Event

Reception hosted by the WMU Department of Mathematics, Fetzer Center, Main Lobby, Saturday, October 18, 6:00 p.m.–7:00 p.m.

Parking

The Fetzer Center provides complimentary parking directly adjacent to the building. More information is provided on the Fetzer Center website http://www.wmich.edu/fetzer/location/parking.html.

Registration and Meeting Information

The meeting will be held on the campus of Western Michigan University. All of the activities for the meeting, including registration, invited lectures, special sessions, and book exhibit will take place in the John E. Fetzer Center (Fetzer Center) and Schneider Hall. Lecture rooms will be equipped with a computer projector, overhead projector, screen, blackboards and/or white boards.

The registration desk will be in the Fetzer Center and will be open from noon until 4:30 p.m. on Friday, October 17, and 7:30 a.m.–4:00 p.m. on Saturday, October 18. Fees are US$40 for AMS or CMS members, US$60 for nonmembers; and US$5 for students/unemployed/emeritus, payable on site by cash, check or credit card.

Travel

Kalamazoo is located midway between Chicago and Detroit, 140 miles from each, 2.5 hours driving time on I-94. Kalamazoo offers commercial transportation by train, bus, and major airline. For information regarding ground transportation visit http://www.azoairport.com/info/ground_transport.html.

Kalamazoo/Battle Creek International Airport (AOZ) is located approximately 10 miles from the campus and is served by the following airlines: Northwest, Comair/Delta Connection, American Eagle, and United Express.

Driving: Strategically located midway between Chicago and Detroit, the Fetzer Center is easily accessible from both I-94 and U.S. 131.

- **From I-94 Detroit (east) and Chicago (west)**

At Exit #75, turn north onto Oakland Drive, drive 2.7 miles; turn left onto Howard Street, go 1.1 miles; turn right onto West Michigan Avenue. Follow the roundabout to the second turn, which is Rankin, and exit. Go to the stop sign, turn right onto Business Court, then left into the large parking lot, then immediately right into the Fetzer Center parking area, Lot #72F.

- **From US 131 (North) Grand Rapids, Muskegon**

At Exit #36A, turn east onto Stadium Drive, drive 2.2 miles to Howard Street. Turn left and go 0.6 miles, turn right onto West Michigan Avenue. Follow the roundabout to the second turn, which is Rankin, and exit. Go to the stop sign and turn right onto Business Court, then left into the large parking lot, then immediately right into the Fetzer Center parking area, Lot #72F.

- **From M-43 North of Kalamazoo**

Follow westbound M-43 through downtown Kalamazoo (Gull Road–Riverview Avenue–East Michigan Avenue–Kalamazoo Avenue–West Main Street) until reaching Solon Street (the fourth traffic light after Kalamazoo Avenue merges with West Main Street and becomes two-way traffic, near Kalamazoo College). Turn left onto Solon and drive south 0.5 miles where Solon turns into Howard Street. At the light turn left onto West Michigan Avenue. Follow the roundabout to the second turn, which is Rankin, and exit. Go to the stop sign and turn right onto Business Court, then left into the large parking lot, then immediately right into the Fetzer Center parking area, Lot #72F.

- **From M-43 West of Kalamazoo**

Drive easterly past US 131. After 1.9 miles, turn right onto Solon Avenue and drive south 0.5 miles where Solon turns into Howard Street. At the light turn left onto West Michigan Avenue. Follow the roundabout to the second turn, which is Rankin, and exit. Go to the stop sign and turn right onto Business Court, then left into the large parking lot, then immediately right into the Fetzer Center parking area, Lot #72F.

- **From Downtown Kalamazoo**

Drive westerly on Stadium Drive (Business Route 131). At Howard Street turn right and drive 0.6 miles; at the light turn right onto West Michigan Avenue. Follow the roundabout to the second turn, which is Rankin, and exit. Go to the stop sign and turn right onto Business Court, then left into the large parking lot, then immediately right into the Fetzer Center parking area, Lot #72F.

Car Rental: **Avis** is the official car rental company for the sectional meeting in Kalamazoo. All rates include unlimited free mileage. Weekend daily rates are available from noon Thursday to Monday at 11:59 p.m. and start at US$30.00 per day. Rates for this meeting are effective October 10, 2008–October 27, 2008. Should a lower qualifying rate become available at the time of booking, Avis is pleased to offer a 5% discount off the lower qualifying rate or the meeting rate, whichever is lowest. Rates do not include any state or local surcharges, tax, optional coverages, or gas refueling charges. Renters must meet Avis' age, driver, and credit requirements. Reservations can be made by calling 1-800-331-1600 or online at http://www.avis.com. **Meeting Avis Discount Number J098887**.

Weather

Typical cool but mild autumn weather prevails in October, with average temperatures 42–62° Fahrenheit.

Information for International Participants

Visa regulations are continually changing for travel to the United States. Visa applications may take from three to four months to process and require a personal interview, as well as specific personal information. International participants should view the important information about traveling to the U.S. found at http://www7.nationalacademies.org/visas/Traveling_to_US.html and http://travel.state.gov/visa/index.html. If you need a preliminary conference invitation in order to secure a visa, please send your request to dls@ams.org.

If you discover you do need a visa, the National Academies website (see above) provides these tips for successful visa applications:

* Visa applicants are expected to provide evidence that they are intending to return to their country of residence. Therefore, applicants should provide proof of "binding" or sufficient ties to their home country or permanent residence abroad. This may include documentation of the following:

- family ties in home country or country of legal permanent residence
- property ownership
- bank accounts
- employment contract or statement from employer stating that the position will continue when the employee returns;

* Visa applications are more likely to be successful if done in a visitor's home country than in a third country;

* Applicants should present their entire trip itinerary, including travel to any countries other than the United States, at the time of their visa application;

* Include a letter of invitation from the meeting organizer or the U.S. host, specifying the subject, location and dates of the activity, and how travel and local expenses will be covered;

* If travel plans will depend on early approval of the visa application, specify this at the time of the application;

* Provide proof of professional scientific and/or educational status (students should provide a university transcript).

This list is not to be considered complete. Please visit the websites above for the most up-to-date information.

Huntsville, Alabama

University of Alabama, Huntsville

October 24–26, 2008

Friday – Sunday

Meeting #1044

Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: August 2008
Program first available on AMS website: September 11, 2008
Program issue of electronic *Notices*: October 2008
Issue of *Abstracts*: Volume 29, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: September 2, 2008

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Mark Behrens, Massachusetts Institute of Technology, *Congruences amongst modular forms and the stable homotopy groups of spheres.*

Anthony M. Bloch, University of Michigan, Ann Arbor, *Variational principles and nonholonomic dynamics.*

Roberto Camassa, University of North Carolina, Chapel Hill, *Title to be announced.*

Mark V. Sapir, Vanderbilt University, *Geometry of groups, random walks, and polynomial maps over finite fields.*

Special Sessions

Applications of PDEs and ODEs (in honor of Karen Ames) (Code: SS 6A), **Suzanne M. Lenhart** and **Philip W. Schaefer**, University of Tennessee, Knoxville.

Applications of Topology to Dynamical Systems (Code: SS 11A), **John C. Mayer** and **Lex G. Oversteegen**, University of Alabama at Birmingham.

Applied Probability (Code: SS 10A), **Moonyu Park** and **Boris Kunin**, University of Alabama in Huntsville.

Dynamics and Applications of Differential Equations (Code: SS 3A), **Wenzhang Huang** and **Shangbing Ai**, University of Alabama in Huntsville, and **Weishi Liu**, University of Kansas.

Gaussian Analysis and Stochastic Partial Differential Equations (Code: SS 4A), **Davar Khoshnevisan**, University of Utah, and **Dongsheng Wu**, University of Alabama in Huntsville.

Geometric Mechanics, Control, and Integrability (Code: SS 8A), **Anthony M. Bloch**, University of Michigan, Ann Arbor, and **Dmitry Zenkov**, North Carolina State University.

Graph Decompositions (Code: SS 2A), **Robert A. Beeler** and **Robert B. Gardner**, East Tennessee State University.

Graph Theory (Code: SS 5A), **Peter J. Slater** and **Grant Zhang**, University of Alabama in Huntsville.

Homotopy Theory and Algebraic Topology (Code: SS 13A), **Mark Behrens**, Massachusetts Institute of Technology, and **Michael Hill**, University of Virginia.

Inverse Limits and Their Applications (Code: SS 14A), **Judy A. Kennedy**, Lamar University.

Mathematical Biology: Modeling, Analysis, and Simulations (Code: SS 1A), **Jia Li**, University of Alabama in Huntsville, **Azmy S. Ackleh**, University of Louisiana at Lafayette, and **Maia Martcheva**, University of Florida.

Nonlinear Operator Theory and Partial Differential Equations (Code: SS 7A), **Claudio H. Morales**, University of Alabama in Huntsville, and **Pei-Kee Lin**, University of Memphis.

Probability on Discrete and Algebraic Structures (Code: SS 9A), **Kyle T. Siegrist**, University of Alabama in Huntsville.

Random Matrices (Code: SS 12A), **Leonard N. Choup**, University of Alabama in Huntsville.

Set-Theoretic Topology (Code: SS 15A), **Gary Gruenhage**, Auburn University, **Peter J. Nyikos**, University of South Carolina, and **Robert M. Stephenson Jr.**, University of South Carolina.

Accommodations

Participants should make their own arrangements directly with a hotel of their choice as early as possible. Special rates have been negotiated with the hotels listed below. Rates quoted do not include sales tax of 12%, plus the city fee of US$1/night. The AMS is not responsible for rate changes or for the quality of the accommodations. When making a reservation, participants should state that they are with the **American Mathematical Society (AMS) Meeting at UAH Math** group. Cancellation and early checkout policies vary; be sure to check when you make your reservation.

Huntsville Marriott Hotel, 5 Tranquility Base, Huntsville, AL 35805; 256-830-2222; fax: 256-895-0904; US$89/single or double (king or two doubles), coffee and coffee maker in room, high-speed Internet access (fee charged), free parking, fitness center with sauna and jacuzzi, indoor/outdoor heated pool, computer/printer in lobby to print boarding passes. Full service restaurant and lounge on premises. The hotel is located on the grounds of the U.S. Space and Rocket Center, the world's largest space museum. **Deadline for reservations is October 3, 2008**. Be sure to check cancellation and early checkout policies.

Bevill Conference Center & Hotel, 550 Sparkman Drive, on the UAH campus; 256-721-9428 or 888-721-9428 toll-free; fax: 704-892-9402; US$59/single or US$62/doubles or one king (one or two people) includes complimentary deluxe continental buffet breakfast with hot items; mini-refrigerator, microwave, and coffee maker in rooms; complimentary pass to the University Fitness Center; free wireless. Limited shuttle service to/from airport, restaurants, and local attractions (Friday, 8:30 a.m.–3:30 p.m. and Sunday, 3:00 p.m.–11:00 p.m.) **Deadline for reservations is September 30, 2008.** Be sure to check cancellation and early checkout policies.

Food Service

Information will be available at the meeting.

Local Information

The university's website is `http://www.uah.edu`; the department of mathematics is at `http://www.math.uah.edu`.

Other Activities

Book Sales: Stop by the on-site AMS Bookstore and review the newest titles from the AMS, enter the free book drawing, enjoy up to 25% off all AMS publications, or take home an AMS t-shirt! Complimentary coffee will be served courtesy of AMS Membership Services.

AMS Editorial Activity: An acquisitions editor from the AMS book program will be present to speak with prospective authors. If you have a book project that you would like to discuss with the AMS, please stop by the book exhibit.

Parking

Watch the AMS website at `http://www.ams.org/amsmtgs/sectional.html` for updated information on parking.

Registration and Meeting Information

The meeting is on the campus of the University of Alabama in Huntsville. Invited Addresses, sessions, and registration will take place in the Shelby Center for Science and Technology.

The registration desk will be open Friday, October 24, noon to 4:00 p.m., and Saturday, October 25, 7:30 a.m. to 4:00 p.m.; it will not be open on Sunday, October 26. Fees are US$40 for AMS or CMS members, US$60 for nonmembers; and US$5 for students, unemployed mathematicians, and emeritus members. Fees are payable on site by cash, check, or credit card.

Travel, Campus Map, and Directions

A good campus map is found at `http://www.uah.edu/map`. The nearest airport is Huntsville International Airport, 1000 Glenn Hearn Blvd., Huntsville, AL 35824; 256-772-9395, fax: 256-772-0305 or `info@hsvairport.org`, and is just over ten miles from the university. A one-way taxi fare to campus is about US$30 for the 20-minute ride.

Driving directions to campus from the airport: Go toward International Way, SW and take the ramp onto I-565 East toward Huntsville and proceed about 7.7 miles. Take exit #15/Madison Pike/Sparkman Drive/Bob Wallace Ave. toward Sparkman Dr. Continue on Sparkman until you see the university on your right.

Weather

October temperatures in Huntsville range from 50° F to 73° F. While October is one of the drier months averaging just 3.52" of rainfall, bringing an umbrella is advisable.

Information for International Participants

Visa regulations are continually changing for travel to the United States. Visa applications may take from three to four months to process and require a personal interview, as well as specific personal information. International participants should view the important information about traveling to the U.S. found at http://www7.nationalacademies.org/visas/Traveling_to_US.html and http://travel.state.gov/visa/index.html. If you need a preliminary conference invitation in order to secure a visa, please send your request to dls@ams.org.

If you discover you do need a visa, the National Academies website (see above) provides these tips for successful visa applications:

* Visa applicants are expected to provide evidence that they are intending to return to their country of residence. Therefore, applicants should provide proof of "binding" or sufficient ties to their home country or permanent residence abroad. This may include documentation of the following:

- family ties in home country or country of legal permanent residence
- property ownership
- bank accounts
- employment contract or statement from employer stating that the position will continue when the employee returns;

* Visa applications are more likely to be successful if done in a visitor's home country than in a third country;

* Applicants should present their entire trip itinerary, including travel to any countries other than the United States, at the time of their visa application;

* Include a letter of invitation from the meeting organizer or the U.S. host, specifying the subject, location and dates of the activity, and how travel and local expenses will be covered;

* If travel plans will depend on early approval of the visa application, specify this at the time of the application;

* Provide proof of professional scientific and/or educational status (students should provide a university transcript).

This list is not to be considered complete. Please visit the websites above for the most up-to-date information.

Shanghai, People's Republic of China

Fudan University

December 17–21, 2008

Wednesday – Sunday

Meeting #1045

First Joint International Meeting Between the AMS and the Shanghai Mathematical Society
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: June 2008
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: October 31, 2008

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/internmtgs.html.

Invited Addresses

L. Craig Evans, University of California Berkeley, *Title to be announced.*

Zhi-Ming Ma, Chinese Academy of Sciences, *Title to be announced.*

Richard Schoen, Stanford University, *Title to be announced.*

Richard Taylor, Harvard University, *Title to be announced.*

Xiaoping Yuan, Fudan University, *Title to be announced.*

Weiping Zhang, Chern Institute, *Title to be announced.*

Special Sessions

Biomathematics: Newly Developed Applied Mathematics and New Mathematics Arising from Biosciences, **Banghe Li**, Chinese Academy of Sciences, **Reinhard C. Laubenbacher**, Virginia Bioinformatics Institute, and **Jianju Tian**, College of William and Mary.

Combinatorics and Discrete Dynamical Systems, **Reinhard C. Laubenbacher**, Virginia Bioinformatics Institute, **Klaus Sutner**, Carnegie Mellon University, and **Yaokun Wu**, Shanghai Jiao Tong University.

Differential Geometry and Its Applications, **Jianguo Cao**, University of Notre Dame, and **Yu Xin Dong**, Fudan University.

Dynamical Systems Arising in Ecology and Biology, **Qishao Lu**, Beijing University of Aeronautics & Astronautics, and **Zhaosheng Feng**, University of Texas-Pan American.

Elliptic and Parabolic Nonlinear Partial Differential Equations, **Changfeng Gui**, University of Connecticut, and **Feng Zhou**, East China Normal University.

Harmonic Analysis and Partial Differential Equations with Applications, **Yong Ding**, Beijing Normal University, and **Guo-Zhen Lu**, Wayne State University.

Integrable System and Its Applications, **En-Gui Fan**, Fudan University, **Sen-Yue Lou**, Shanghai Jiao Tong University and Ningbo University, and **Zhi-Jun Qiao**, University of Texas-Pan American.

Integral and Convex Geometric Analysis, **Deane Yang**, Polytechnic University, and **Jiazu Zhou**, Southwest University.

Lie Algebras, Vertex Operator Algebras and Related Topics, **Hu Nai Hong**, East China Normal University, and **Yi-Zhi Huang**, Rutgers University.

Nonlinear Systems of Conservation Laws and Related Topics, **Gui-Qiang Chen**, Northwestern University, and **Shuxing Chen** and **Yi Zhou**, Fudan University.

Optimization and Its Application, **Shu-Cherng Fang**, North Carolina State University, and **Xuexiang Huang**, Fudan University.

Quantum Algebras and Related Topics, **Naihuan N. Jing**, North Carolina State University, **Quanshui Wu**, Fudan University, and **James J. Zhang**, University of Washington.

Recent Developments in Nonlinear Dispersive Wave Theory, **Jerry Bona**, University of Illinois at Chicago, **Bo Ling Guo**, Institute of Applied Physics and Computational Mathematics, **Shu Ming Sun**, Virginia Polytech Institute and State University, and **Bingyu Zhang**, University of Cincinnati.

Representation of Algebras and Groups, **Birge K. Huisgen-Zimmermann**, University of California Santa Barbara, **Jie Xiao**, Tsinghua University, **Jiping Zhang**, Beijing University, and **Pu Zhang**, Shanghai Jiao Tong University.

Several Complex Variables and Applications, **Siqi Fu**, Rutgers University, **Min Ru**, University of Houston, and **Zhihua Chen**, Tongji University.

Several Topics in Banach Space Theory, **Gerard J. Buskes** and **Qingying Bu**, University of Mississippi, and **Lixin Cheng**, Xiamen University.

Stochastic Analysis and Its Application, **Jiangang Ying**, Fudan University, and **Zhenqing Chen**, University of Washington.

Topics in Partial Differential Equations and Mathematical Control Theory, **Xiaojun Huang**, Rutgers University, **Gengsheng Wang**, Wuhan University of China, and **Stephen S.-T. Yau**, University of Illinois at Chicago.

Washington, District of Columbia

Marriott Wardman Park Hotel and Omni Shoreham Hotel

January 5–8, 2009

Monday – Thursday

Meeting #1046

Joint Mathematics Meetings, including the 115th Annual Meeting of the AMS, 92nd Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Bernard Russo

Announcement issue of *Notices*: October 2008

Program first available on AMS website: November 1, 2008

Program issue of electronic *Notices*: January 2009

Issue of *Abstracts*: Volume 30, Issue 1

Deadlines

For organizers: Expired

For consideration of contributed papers in Special Sessions: July 22, 2008

For abstracts: September 16, 2008

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/national.html`.

Joint Invited Addresses

Douglas N. Arnold, University of Minnesota, Minneapolis, *Title to be announced* (AMS-MAA Invited Address).

AMS Invited Addresses

Luis A. Caffarelli, University of Texas at Austin, *Title to be announced.*

Mikhail Khovanov, Institute for Advanced Study, *Title to be announced.*

Girgorii A. Margulis, Yale University, *Title to be announced* (AMS Colloquium Lectures).

Ken Ono, University of Wisconsin-Madison, *Title to be announced.*

Christor Papadimitriou, University of California Berkeley, *Title to be announced.*

Oded Schramm, Microsoft, *Title to be announced* (AMS Josiah Willard Gibbs Lecture).

James A. Sethian, University of California Berkeley, *Title to be announced.*

AMS Special Sessions

Some sessions are cosponsored with other organizations. These are noted within the parenthesis at the end of each listing, where applicable.

Algebraic Cryptography and Generic Complexity (Code: SS 41A), **Vladimir Shpilrain**, The City College of New York, and **Yesem Kurt**, Randolph College.

Algebraic Structures in Knot Theory (Code: SS 33A), **Sam Nelson**, Claremont McKenna College, and **Alissa S. Crans**, Loyola Marymount University.

Asymptotic Geometric Analysis (Code: SS 45A), **Alexander E. Litvak**, University of Alberta, and **Dmitry Ryabogin** and **Artem Zvavitch**, Kent State University.

Asymptotic Methods in Analysis with Applications (Code: SS 19A), **Diego Dominici**, SUNY New Platz, and **Peter A. McCoy**, U.S. Naval Academy (AMS-SIAM).

Automorphic and Modular Forms in Number Theory (Code: SS 55A), **Ken Ono** and **Amada Folsom**, University of Wisconsin-Madison, and **Sharon A. Garthwaite**, Bucknell University.

Categorification and Link Homology (Code: SS 58A), **Aaron Lauda** and **Mikhail Khovanov**, Columbia University.

Commutative Rings (Code: SS 1A), **Jay A. Shapiro**, George Mason University, **David E. Dobbs**, University of

Tennessee, Knoxville, **Shane P. Redmond**, Eastern Kentucky University, and **Joe A. Stickles**, Millikin University.

Complex Dynamics and Complex Function Theory (Code: SS 16A), **Stephanie Edwards**, Hope College, and **Rich L. Stankewitz**, Ball State University.

Computational Algebra and Convexity (Code: SS 9A), **Henry K. Schenck**, University of Illinois at Urbana-Champaign, **Michael Stillman**, Cornell University, and **Jan Verschelde**, University of Illinois at Chicago.

Computational Algebraic and Analytic Geometry for Low-dimensional Varieties (Code: SS 48A), **Mika K. Seppälä**, Florida State University, **Tanush Shaska**, Oakland University, and **Emil J. Volcheck**, Association for Computing Machinery.

Conformal Geometry, Twistor Theory, and Integrable Systems (Code: SS 36A), **Dana Mihai**, Carnegie Mellon University, and **George Sparling**, University of Pittsburgh.

Continued Fractions (Code: SS 50A), **James G. McLaughlin**, West Chester University, and **Nancy J. Wyshinski**, Trinity College.

Convex and Discrete Geometry (Code: SS 10A), **Wlodzimierz Kuperberg**, Auburn University, and **Valeriu Soltan**, George Mason University.

Difference Equations (Code: SS 4A), **Michael Radin**, Rochester Institute of Technology.

Discrete Dynamical Systems in Periodic Environments (Code: SS 38A), **M. R. S. Kulenović** and **Orlando Merino**, University of Rhode Island, and **Abdul-Aziz Yakubu**, Howard University.

Dynamical Systems and Differential Equations: Theory and Applications (Code: SS 44A), **Annalisa Crannell**, Franklin & Marshall College, and **Suzanne Sindi**, Brown University.

Experimental Mathematics (Code: SS 27A), **Tewodros Amdeberhan**, **Luis A. Medina**, and **Victor H. Moll**, Tulane University.

Financial Mathematics (Code: SS 42A), **Erhan Bayraktar**, University of Michigan, and **Tim Siu-Tang Leung**, Princeton University.

Geometry, Algebra, and Topology of Character Varieties (Code: SS 29A), **Sean Lawton**, Instituto Superior Tecnico, and **Elisha Peterson**, United States Military Academy.

Group Actions on Curves (Code: SS 31A), **Darren Glass**, Gettysburg College, and **Amy E. Ksir**, United States Naval Academy.

Group Actions on Homogeneous Spaces and Applications (Code: SS 57A), **Dimtry Y. Kleinbock**, Brandeis University, **Gregory A. Margulis**, Yale University, and **Hee Oh**, Brown University.

Harmonic Analysis (Code: SS 49A), **Paul A. Hagelstein**, Baylor University, and **Alexander M. Stokolos**, Depaul University.

Heavy-Tailed Behavior: Theory and Applications (Code: SS 28A), **Thomas B. Fowler**, **Marty Fischer**, and **Denise Masi**, Noblis Incorporated, and **John F. Shortle**, George Mason University.

History of Mathematics (Code: SS 17A), **Joseph W. Dauben**, Lehman College, **Karen H. Parshall**, University of Virginia, **Patti Hunter**, Westmont College, and **Deborah Kent**, Hillsdale College (AMS-MAA).

Homotopy Theory and Higher Categories (Code: SS 3A), **Thomas M. Fiore**, University of Chicago, **Mark W. Johnson**, Penn State Altoona, **James M. Turner**, Calvin College, **W. Stephen Wilson**, Johns Hopkins University, and **Donald Yau**, Ohio State University at Newark.

Infinite Dimensional Analysis, Path Integrals and Related Fields (Code: SS 46A), **Tepper L. Gill**, Howard University, **Lance W. Nielsen**, Creighton University, and **Woodford W. Zachary**, Howard University.

Inquiry-Based Learning (Code: SS 35A), **William B. Jacob**, University of California Santa Barbara, **Paul J. Sally**, University of Chicago, **Ralf J. Spatzier**, University of Michigan, and **Michael Starbird**, University of Texas at Austin (AMS-MAA).

Logic and Dynamical Systems (Code: SS 12A), **Stephen G. Simpson**, Pennsylvania State University (AMS-ASL).

MAA General Contributed Paper Session (Code: MAACPZ7), **Sarah L. Mabrouk**, Framingham State University (AMS-MAA-MER).

Mathematical Models of Biological Structures and Function (Code: SS 32A), **Chandrajit Bajaj** and **Andrew K. Gillette**, University of Texas at Austin.

Mathematics and Education Reform (Code: SS 52A), **William H. Barker**, Bowdoin College, **William G. McCallum**, University of Arizona, and **Bonnie S. Saunders**, University of Illinois at Chicago (AMS-MAA-MER).

Mathematics and Mathematics Education in Fiber Arts (Code: SS 30A), **Sarah-Marie Belcastro**, The Hampshire College Summer Studies in Mathematics, and **Carolyn A. Yackel**, Mercer University.

Mathematics of Computation (Code: SS 43A), **Susanne C. Brenner**, Louisiana State University, and **Chi-Wang Shu**, Brown University.

Model Theoretic Methods in Finite Combinatorics (Code: SS 18A), **Martin Grohe**, Humboldt University, and **Johann A. Makowsky**, Technion Israel Institute of Technology (AMS-ASL).

New Connections Between Topology, Combinatorics, and Physics (Code: SS 23A), **Paul Fendley** and **Slava Krushkal**, University of Virginia.

Noncommutative Algebra (Code: SS 39A), **Greg Marks** and **Ashish K. Srivastava**, St. Louis University.

Nonlinear Evolution Equations and Their Applications (Code: SS 34A), **Gaston N'Guerekata**, **Alexander A. Pankov**, **Guoping Zhang**, and **Xuming Xie**, Morgan State University, and **Zhijun Qiao**, University of Texas Pan American.

Nonlinear Partial Differential Equations and Applications (Code: SS 20A), **Gui-Qiang G. Chen**, Northwestern University, and **Cleopatra C. Christoforou**, University of Houston.

Nonsmooth Analysis in Inverse and Variational Problems (Code: SS 47A), **M. Zuhair Nashed**, University of Central Florida, and **Otmar Scherzer**, University of Innsbruck.

Operator Theoretic Function Theory (Code: SS 13A), **John B. Conway**, George Washington University, **Sherwin Kouchekian**, University of South Florida, and **William T. Ross**, University of Richmond.

Orderings in Logic and Topology (Code: SS 54A), **Valentina S. Harizanov** and **Jozef H. Przytycki**, George Washington University.

Recent Advances in Mathematical Modeling in Medicine (Code: SS 21A), **David Chan**, **John W. Cain**, and **Rebecca A. Segal**, Virginia Commonwealth University.

Recent Trends in Coding Theory (Code: SS 14A), **Gretchen L. Matthews**, Clemson University, and **Judy L. Walker**, University of Nebraska.

Representation Theory of Lie Algebras and Algebraic Groups (Code: SS 15A), **David G. Taylor**, Roanoke College, **Terrell L. Hodge**, Western Michigan University, and **Daniel K. Nakano**, University of Georgia.

Research in Mathematics by Undergraduates (Code: SS 22A), **Darren A. Narayan**, Rochester Institute of Technology, **Jacqueline A. Jensen**, Sam Houston State University, **Carl V. Lutzer**, Rochester Institute of Technology, **Vadim Ponomarenko**, San Diego State University, and **Tamas Wiandt**, Rochester Institute of Technology (AMS-MAA-SIAM).

Role of Generalized Maximal Monotonicity Frameworks in Optimization and Control Theory with Applications (Code: SS 6A), **Ram U. Verma**, International Publications.

SAGE and Mathematical Research Using Open Source Software (Code: SS 2A), **William A. Stein**, University of Washington, Seattle, **David Saunders**, University of Delaware, **David Harvey**, Harvard University, and **David Joyner**, U.S. Naval Academy.

Scientific Computing and Advanced Computation (Code: SS 8A), **John B. Bell**, Lawrence Berkeley National Lab, **Randall J. LeVeque**, University of Washington, and **Juan C. Meza**, Lawrence Berkeley National Lab.

Spectra of Matrix Patterns and Applications to Dynamical Systems (Code: SS 40A), **Bryan L. Shader**, University of Wyoming, **Luz M. DeAlba**, Drake University, **Leslie Hogben**, Iowa State University, and **In-Jae Kim**, Minnesota State University.

Stochastic, Large-Scale, and Hybrid Systems with Applications (Code: SS 26A), **Aghalaya S. Vatsala**, University of Louisiana at Lafayette, and **G. S. Ladde** and **K. Ramachandran**, University of South Florida.

Teichmüller Theory and Low-Dimensional Topology (Code: SS 7A), **Francis Bonahon**, University of Southern California, **Howard Masur**, University of Chicago, **Abigail A. Thompson**, University of California Davis, and **Genevieve Walsh**, Tufts University.

The Mathematics of Information and Knowledge (Code: SS 53A), **Ronald R. Coifman**, Yale University, **James G. Glimm**, SUNY at Stony Brook, **Peter W. Jones**, Yale University, and **Stephen Smale**, Toyota Institute.

The Redistricting Problem (Code: SS 51A), **Daniel Goroff**, Harvey Mudd College, and **Dan Ullman**, George Washington University.

The Scholarship of Teaching and Learning (Code: SS 24A), **Curtis D. Bennett** and **Jacqueline M. Dewar**, Loyola Marymount University (AMS-MAA).

Topological Methods in Applied Mathematics (Code: SS 56A), **Yongwu Rong**, George Washington University.

Von Neumann Algebras (Code: SS 37A), **Pinhas Grossman**, Vanderbilt University, and **Remus Nicoara**, University of Tennessee.

Call for MAA Contributed Papers

The MAA Committee on Contributed Paper Sessions solicits contributed papers pertinent to the sessions listed below. Contributed paper session organizers generally limit presentations to 15 minutes with a five-minute break between talks; in the general session talks are limited to 10 minutes with a five-minute break. Each session room contains a computer projector, an overhead projector, and a screen. Please note that the dates and times scheduled for these sessions remain tentative.

Assessment of Student Learning in Undergraduate Mathematics, Wednesday afternoon, **William O. Martin**, North Dakota State University, and **Bernard L. Madison**, University of Arkansas. Assessment continues to be an important issue for the mathematical sciences, with increasing faculty involvement in assessment activities. Departments are expected to document assessment activities focusing on student learning in general education, the major, and graduate programs for program review and institutional accreditation. We encourage faculty to disseminate information about their experiences by inviting contributed papers that (a) describe assessment projects in undergraduate mathematics programs, including the areas of quantitative literacy, general education, and the major; (b) report findings of those projects; and (c) describe faculty and departmental responses to those findings. Papers are solicited from any individuals or groups actively involved in assessment.

Building Diversity in Advanced Mathematics: Models that Work, Monday afternoon, **Patricia L. Hale**, California State Polytechnic University Pomona, and **Abbe Herzig**, University at Albany. Papers presented at this session give models of programs that have been successful at supporting diverse groups of people (women of all races, African Americans, Latinos and Chicanos, and Native Americans, people of all economic groups, people with disabilities) in their pursuit of advanced mathematics study and careers. Presentations will span the educational pathway, since issues of diversity need to be addressed at every educational and professional juncture. Proposals are sought that describe successful programs for post-doctoral (faculty), graduate, undergraduate or pre-college students. We interpret "success" broadly, and are looking for ideas that should be shared with others in the mathematics community as models for promoting diversity across the educational spectrum. These might be academic or extracurricular programs, which have targeted any group of people traditionally underrepresented in the mathematical sciences. Historical perspectives are also welcome.

College Algebra: Focusing on Conceptual Understanding, Real-World Data, and Mathematical Modeling, Thursday morning, **Florence S. Gordon**, New York Institute of Technology; **Laurette B. Foster**, Prairie View A&M University; **Yajun Yang**, Farmingdale State College; and **Ray E. Collings**, Georgia Perimeter College. The MAA, under the leadership of CRAFTY, is conducting a national initiative

to refocus the courses below calculus to better serve the majority of students taking these courses. The goal is to encourage courses that place much greater emphasis on conceptual understanding and realistic applications compared to traditional courses that too often are designed to develop algebraic skills needed for calculus.

We seek talks addressing all the college level courses below calculus, particularly college algebra and precalculus, that focus on conceptual understanding, the use of real-world data, and mathematical modeling. We seek presentations that present new visions for such courses; discuss experiences teaching such courses; discuss implementation issues (such as faculty training, placement, introduction of alternative tracks for different groups of students, transferability issues, etc); present results of studies on student performance and tracking data in both traditional and new versions of these courses and in follow-up courses; discuss the needs of other disciplines and the workplace from courses at this level; and/or discuss connections to the changing high school curricula and implications for teacher education. The session is cosponsored by CRAFTY and the Committee on Two-Year Colleges.

Cryptology for Undergraduates, Monday afternoon, **Chris Christensen**, Northern Kentucky University, and **Robert E. Lewand**, Goucher College. In increasing numbers cryptology courses are being developed to serve the needs of undergraduate mathematics and computer science majors. For mathematics majors cryptology fits into the undergraduate curriculum in much the same way that number theory does. In addition cryptology is appearing as a topic in mathematics courses for nonmajors, as it is a hook to interest these students in mathematics. This session solicits presentations that address topics appropriate for undergraduate cryptology courses for mathematics or computer science majors, or presentations of cryptological topics that could interest and motivate nonmathematics majors.

Demos and Strategies with Technology that Enhance Teaching and Learning Mathematics, Tuesday morning and afternoon. **David R. Hill**, Temple University; **Scott Greenleaf**, University of New England; **Mary L. Platt**, Salem State College; and **Lila F. Roberts**, Georgia College & State University. Mathematics instructors use an ever expanding variety of instructional strategies to teach mathematical concepts. As new technologies emerge, instructors employ them in interesting ways as a means to boost creativity and flexibility in lesson design. Tools an instructor utilizes may include specialized computer applications, animations (possibly with audio), and other multimedia tools on standard delivery platforms or handheld devices. This session will focus on novel demos, projects, or labs that mathematics instructors have successfully used in their classrooms that support conceptual understanding. Presenters are encouraged to illustrate their approach with the technology, if time and equipment allow, and to discuss how it is employed in the classroom. Proposals should describe how the presentation with technology fits into a course, the effect it has had on student attitudes toward mathematics, and include a summary of any assessment techniques employed. The session is endorsed by CTiME (Committee on Technology in Mathematics Education).

Developmental Mathematics Education: Helping Under-Prepared Students Transition to College-Level Mathematics, Thursday morning, **J. Winston Crawley** and **Kimberly Presser**, Shippensburg University. Many students are arriving at college today under-prepared for college-level mathematics courses. In order to help these students to be successful, we need to undertake new strategies for support services, courses offered, and perhaps even in our programs themselves. This session invites papers on all aspects of developmental mathematics education. In particular what classroom practices are effective with such students and how does research in student learning inform these practices? For students interested in math-intensive majors such as the sciences, how can we best prepare these students for several subsequent mathematics courses? How can we best coordinate support services with the courses offered in our mathematics departments?

Environmental Mathematics, Monday afternoon, **Karen Bolinger**, Clarion University, and **Ben A. Fusaro**, Florida State University. We invite presentations that apply undergraduate mathematics to solve environmental problems. We also invite presentations on expositional and pedagogical aspects of environmental mathematics. This session is sponsored by the SIGMAA Environmental Mathematics.

Guided Discovery in Mathematics Education, Thursday afternoon, **Jerome S. Epstein**, Polytechnic University. Following on a good session on the topic for JMM-2008, we are again soliciting contributions for 2009 on a topic which we believe to be of central importance for the further development of quality programs in mathematics education at all levels. We seek papers on: (1) programs with more than anecdotal evidence of efficacy, or the lack thereof; (2) means of assessment used to determine efficacy of discovery-based programs; (3) well thought out papers on the operational meaning of terms such as "Guided Discovery", and thus on what specific aspects of programs actually are responsible for any observed differences in outcomes; and/or (4) differences in outcomes in later mathematics courses for those in discovery-based programs vs. traditional lecture-based. The session is sponsored by SIGMAA on Research in Undergraduate Mathematics Education (SIGMAA on RUME).

Innovative and Effective Ways to Teach Linear Algebra, Tuesday morning and afternoon, **David M. Strong**, Pepperdine University; **Gil Strang**, Massachusetts Institute of Technology; and David C. Lay, University of Maryland. Linear algebra is one of the most interesting and useful areas of mathematics, because of its beautiful and multifaceted theory, as well as the enormous importance it plays in understanding and solving many real world problems. Consequently, many valuable and creative ways to teach its rich theory and its many applications are continually being developed and refined. This session will serve as a forum in which to share and discuss new or improved teaching ideas and approaches. These innovative and effective ways to teach linear algebra include, but are not necessarily

limited to (1) hands-on, in-class demos; (2) effective use of technology, such as Matlab, Maple, Mathematica, Java Applets or Flash; (3) interesting and enlightening connections between ideas that arise in linear algebra and ideas in other mathematical branches; (4) interesting and compelling examples and problems involving particular ideas being taught; (5) comparing and contrasting visual (geometric) and more abstract (algebraic) explanations of specific ideas; and (6) other novel and useful approaches or pedagogical tools.

Mathematics and the Arts, Thursday morning and afternoon, **Douglas E. Norton**, Villanova University. This session invites presentations of results on the connections between mathematics and the arts: mathematical aspects of arts, music, and architecture, as well as artistic representations of mathematical objects, ideas, and theorems. We invite explorations of connections old and new: tilings, architecture, quilting, cross-stitch, painting, sculpture, musical composition and analysis, mathematical properties of or themes in poetry and literature, and new technological explorations. The math-arts connection is not just about Escher and the golden mean any more! (These topics are not excluded, of course.) The sharing of experiences and ideas for incorporation into course design and classroom activities is also encouraged. The session is sponsored by the SIGMAA on Mathematics and the Arts.

Mathematics of Chemistry, Monday afternoon, **George T. Rublein**, College of William and Mary, and **Thomas R. Hagedorn**, The College of New Jersey. Mathematics makes its appearance early on in college-level chemistry courses. Physical chemistry, which is heavily laced with mathematical models, has a reputation as the most difficult course in the undergraduate chemistry curriculum. The treatment of mathematics in chemistry textbooks often bears little resemblance to the approaches that students see in mathematics courses. This session solicits contributions that show examples of models drawn from chemistry that might comfortably appear in the calculus, differential equations or linear algebra courses in which chemistry students are commonly enrolled. Chemical thermodynamics, stoichiometry, and chemical kinetics are good sources for such models.

Mathematics Experiences in Business, Industry, and Government, Wednesday morning, **Philip Gustafson**, Mesa State College, and **Michael Monticino**, University of North Texas. This session will provide a forum for mathematicians with experience in business, industry, and government (BIG) to present papers or discuss projects involving the application of mathematics to BIG problems. BIG mathematicians as well as faculty and students in academia who are interested in learning more about BIG practitioners, projects, and issues, will find this session of interest. This session is sponsored by the MAA Business, Industry and Government Special Interest Group (BIG SIGMAA).

Mathematics of Games and Puzzles, Tuesday morning, **Laura A. Taalman**, James Madison University. With the recent popularity of Sudoku, the mathematics of games and puzzles is enjoying a renaissance. In addition to those doing mathematical research about the game of Sudoku, people are continuing to research other games and puzzles such as Nim, SET, Rubik's Cube, the 15- puzzle, knight tours, origami, Mancala, cake division, and Japanese pencil puzzles such as Slitherlink, Nurikabe, Heyawake, and Masyu. These puzzles are related to a surprisingly wide variety of mathematical topics, from graph theory, game theory, and NP-completeness to number theory, topology, and integer programming. The mathematical research of games and puzzles is also a fertile ground for undergraduate research projects and for popularizing mathematics. This session invites talks about mathematical research, classroom use, and possible undergraduate research projects that relate to games and puzzles. Handouts of puzzles are encouraged.

Mathematics and Sports, Tuesday morning, **Howard L. Penn**, U. S. Naval Academy. Sports provide a host of applications of mathematics. Examples exist that use concepts taught in calculus, differential equations, probability, statistics, and combinatorics. In this session, we will showcase interesting applications of mathematics in various sports. The application should be suitable for use in the classroom. The mathematics may be at any level from freshman to senior. Talks may be expository or may highlight undergraduate research.

Mathlets for Teaching and Learning Mathematics, Wednesday morning and afternoon, **Thomas E. Leathrum**, Jacksonville State University, **David M. Strong**, Pepperdine University, and **Joe Yanik**, Emporia University. This session seeks to provide a forum in which presenters may demonstrate mathlets and related materials that they have created or further developed. Mathlets are small computer-based (but ideally platform-independent) interactive tools for teaching math, frequently developed as World Wide Web materials such as scripts or Java applets, but there may be many other innovative variations. Mathlets allow students to experiment with and visualize a variety of mathematical concepts, and they can be easily shared by mathematics instructors around the world. This session is sponsored by the MAA Committee on Technology in Mathematics Education (CTiME).

Operations Research in the Undergraduate Classroom, Monday afternoon, **Gerald Kobylski** and **Josh Helms**, U. S. Military Academy, and **William Fox**, Naval Post Graduate School. This session solicits submissions highlighting innovative instructional strategies and assessment methods in the introductory undergraduate operations research courses or sequence. Suggested topics include, but are not limited to, course content, course projects, case studies, technology demonstrations, cooperative learning activities, and writing assignments. Course projects or case studies presented can be from mathematics courses other than operations research but should highlight operations research topics. Talks may focus on original teaching materials or the creative use of previously existing ones, but all talks should provide specific learning objectives addressed by the use of such materials. Each submission must focus on operations research topics at the undergraduate level, including those in the introductory undergraduate operations research sequence or undergraduate courses in stochastic processes, statistical modeling, simulation modeling, queuing theory, networks, linear

optimization, nonlinear optimization, etc., and should be accompanied by a course syllabus.

Performing Mathematics, Monday afternoon, **Timothy P. Chartier**, Davidson College, and **Karl Schaffer**, De Anza College. Performing arts such as juggling, dance, magic, and drama can enrich the mathematics classroom, and reveal intriguing connections between mathematics and the performing arts. Beyond entertaining students and the general public, such demonstrations can offer new and novel perspectives on mathematical content and engage a class in a fun, educational, and interactive activity. This session seeks to provide a forum in which presenters may demonstrate and discuss creative ways of teaching and presenting mathematics using techniques generally associated with entertainment and the performing arts. Proposals should clearly delineate the mathematical subject that will be covered. When a short performance or portion of a performance is included, a presenter might also incorporate a clear discussion of how a presenter's methods can be adapted for general classroom use. Descriptions of classroom activities that are suitable for use by teachers and professors without a performance background are also strongly encouraged.

Productive Roles for Math Faculty in the Professional Development of K–12 Teachers, Wednesday morning, **Dale R. Oliver**, Humboldt State University, and **Elizabeth Burroughs**, Montana State University. This session is a forum for faculty whose involvement in professional development for teachers might be described as "productive". The word productive here implies that the professional development produced some observable improvement in what teachers understand about mathematics, in how they think about and do mathematics, or in their pedagogical practices in teaching mathematics. The faculty who present in this session will highlight the key features of the professional development they delivered, including the structure, content, and pedagogy of the work they did with teachers. Of particular interest to the organizers will be descriptions of partnerships between math faculty and lead K–12 teachers to design and deliver the professional development. This session is sponsored by the MAA Committee on the Mathematical Education of Teachers (COMET).

Promoting Deep Learning for Mathematics Majors through Experiential Learning, Writing, and Reflection, Thursday morning and afternoon, **Murphy Waggoner**, Simpson College, and **Chuck Straley**, Wheaton College. Active and engaged learning helps our students gain genuine ownership of concepts and to become independent thinkers with truly transferable skills. This session is intended to give those who are currently helping students move from surface learning to deep learning to share their ideas with others. We invite presentations that describe ways to promote deep learning within the curriculum for mathematics majors, such as effective internship programs, service learning projects, or other experiential experiences that allow students to apply mathematical skills in real situations; courses that use a discovery method to teach mathematical concepts; innovative teaching techniques that are proven to make concepts "stick"; or the use of writing as a way to help students deepen their understanding of mathematics. Presentations should describe how the learning experiences were developed and how a deeper and lasting understanding of mathematics was demonstrated. Of special interest are presentations that show how to include written and/or oral reflection as a method of strengthening the learning experience.

Quantitative Literacy Across the Curriculum, Wednesday morning, **Kimberly M. Vincent**, Washington State University, and **Cinnamon Hillyard**, University of Washington, Bothell. There are a growing number of colleges and universities with programs that embed QL in various disciplines. We would encourage dissemination of this important work by soliciting papers from any individuals or groups actively involved in quantitative literacy across the curriculum. The need to interpret and make inferences from quantitative data arises in all disciplines. Individuals and teams, who have embedded QL in various disciplines or institution wide, are welcome to submit contributed papers. Papers should provide examples from various disciplines that authentically embed QL in mathematics and/or other curriculum. Preference will be given to abstracts that provide evidence on the impact of the program or projects on student learning. If you have been working with faculty from other disciplines we encourage you to bring these faculty to JMM to present with you. The session is sponsored by SIGMAA-QL.

Research on the Teaching and Learning of Undergraduate Mathematics, Tuesday afternoon, **Keith H. Weber**, Rutgers University; **Michelle J. Zandieh**, Arizona State University; and **Karen A. Marrongelle**, Portland State University. As part of its ongoing activities to foster research in undergraduate mathematics education and the dissemination of such research, the Special Interest Group of the Mathematical Association of America on Research in Undergraduate Mathematics Education (SIGMAA on RUME) solicits reports of research on the learning and teaching of undergraduate mathematics for its contributed paper session. We solicit proposals for research reports presenting results from completed research studies on undergraduate mathematics education that address one or more of the following themes: (1) results of current research; (2) contemporary theoretical perspectives and research paradigms, and (3) innovative methodologies and analytical approaches as they pertain to the study of undergraduate mathematics education. We also welcome preliminary reports on research projects in early stages of development or execution.

Statistics in K–12 Education: How Will It Affect Statistics at the College Level?, Wednesday morning, **Patricia B. Humphrey**, Georgia Southern University, and **Robin H. Lock**, St. Lawrence University. Teaching statistics in K–12 has exploded in the past few years, due both to a change in curriculum in new state standards and the growth of AP Statistics (over 100,000 exams in 2007). Unfortunately, most math teachers at this level are ill-equipped to teach the subject. We seek presentations that illustrate how we can support these teachers (both current and future) via successful pre- and in-service programs and interaction as a "mentor". What preparation should K–12 teachers have?

How will/has this explosion impact teaching introductory statistics at the college level? Has your "intro" course been expanded/modified to (hopefully) adapt to students better prepared for our subject? The session is sponsored by the SIGMAA on Statistics Education and the ASA-MAA Joint Committee on Statistics Education. In order to be considered for this session applicants should submit a one-page summary of the presentation to Pat Humphrey at phumphre@georgiasouthern.edu along with the abstract via the JMM website. Presenters in the session will be considered for the SIGMAA on Statistics Education's Best Contributed Presentation Award.

Statistics Resources on the Web, Wednesday afternoon, **Dorothy W. Anway**, University of Wisconsin, Superior; **Patricia B. Humphrey**, Georgia Southern University; **Christopher J. Lacke**, Rowan University. This session seeks to provide a forum in which presenters may demonstrate web-based applets, mathlets, data sets, activities and related materials they have successfully used in statistics classes. With the proliferation of such resources (try a Google search on "statistical applets"; there are 941,000 results!), endeavoring to find worthwhile resources can be time-consuming and difficult. No one has the time available to do a thorough search and examination when looking for a particular item on any given topic. We invite submissions that detail the following about one or more items found on the Web: what it was, any resources required, how it was used, the time involved (in and out of class), the success and/or failure in terms of pedagogical intent, suggestions for improvement, and the Web address where the resource was found. The intent is that attendees will take away a bag of handy tricks that can be used without "reinventing the wheel". The session is sponsored by the SIGMAA on Statistics Education. In order to be considered for this session, applicants should submit a one-page summary of the presentation to Dorothy Anway at danway@uwsuper.edu in addition to the abstract submitted through the JMM website. Presenters in the session will be considered for the SIGMAA on Statistics Education's Best Contributed Presentation Award.

Teaching Calculus in High School: Ideas that Work, Tuesday morning, **Dan Teague**, North Carolina School of Science and Mathematics, and **John F. Mahoney**, Benjamin Banneker Academic High School. Today, most STEM majors had their introductory calculus course while in high school. SIGMAA TAHSM is committed to assisting teachers in making the mathematical experiences of their students as challenging and exciting as possible. This session will serve as a forum in which to share activities and approaches to teaching calculus that work well with high school students. Of particular interest are projects and investigations, activities, demonstrations, teaching strategies, and techniques that bring the class and the mathematics to life for the students, and illustrate the nature and utility of mathematics. University faculty interested in or concerned about what happens in high school calculus classrooms are encouraged to participate and attend the sessions.

Undergraduate Mathematical Biology, Tuesday, morning and afternoon, **Timothy D. Comar**, Benedictine University, **Raina Robeva**, Sweet Briar College, and **Eric S. Marland**, Appalachian State University. Reports including "BIO 2010: Transforming Undergraduate Education for Future Research Biologists" (National Research Council, 2003) and "Math and BIO 2010: Linking Undergraduate Disciplines" (L. A. Steen, ed., MAA, 2005) emphasize that aspects of biological research are becoming more quantitative and that life science students should be introduced to a greater array of mathematical and computational techniques and to the integration of mathematics and biological content at the undergraduate level. Since these reports, many successful programs and materials have been designed to address these issues. This session is designed to highlight available and successful, print, electronic, or online materials which are available for implementation in the classroom. This session would also like to highlight programs and workshops which have helped train faculty in the pedagogy of undergraduate mathematical biology. The session is particularly interested in presenters who have created materials after participating in workshops offered by the MAA or other professional organizations. We encourage presenters to provide handouts or electronic copies of materials that can readily be used in the classroom. This session is sponsored by the BIO SIGMAA.

General Session, Monday, Tuesday, Wednesday, and Thursday mornings and afternoons; **Sarah L. Mabrouk**, Framingham State University. Papers may be presented on any mathematical topic. Papers that fit into one of the other sessions should be sent to that organizer, not to this session. Note the restriction below that you may give only one talk in this session.

Submission Procedures for MAA Contributed Papers

Send your abstract directly to the meeting website (abstracts should not be sent to the organizer(s) who will automatically receive a copy). Please read the session descriptions thoroughly as some organizers require an additional summary of your proposal be sent to them directly. Participants may speak in at most two MAA contributed paper sessions. If your paper cannot be accommodated in the session for which it was submitted, it will be automatically considered for the general session. Speakers in the general session will be limited to one talk because of time constraints. Abstracts must be submitted by Tuesday, **September 16, 2008**.

All accepted abstracts will be published in a book available at the meeting to all registered participants. Abstracts must be submitted electronically. While no knowledge of LaTeX is necessary for submission, LaTeX and $\mathcal{A}\mathcal{M}\mathcal{S}$-LaTeX are the only typesetting systems that can be used if mathematics or any text markup (e.g., accent marks) is included. The abstracts submissions page is at http://www.ams.org/cgi-bin/abstracts/abstract.pl. Simply select the Washington, D.C. meeting, fill in the number of authors, and proceed with the step-by-step instructions. Submitters will be able to view their abstracts before final submission. Upon completion of your submission, your unique abstract number will immediately be sent to you.

All questions concerning the submission of abstracts should be addressed to abscoord@ams.org.

Urbana, Illinois

University of Illinois at Urbana-Champaign

March 27–29, 2009

Friday – Sunday

Meeting #1047

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 29, 2008
For consideration of contributed papers in Special Sessions: December 9, 2008
For abstracts: February 3, 2009

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Jacob Lurie, Massachusetts Institute of Technology, *Title to be announced*.

Gilles Pisier, Texas A&M University, *Title to be announced*.

Akshay Venkatesh, New York University-Courant Institute, *Title to be announced*.

Special Sessions

Algebra, Geometry and Combinatorics (Code: SS 10A), **Rinat Kedem**, University of Illinois at Urbana-Champaign, and **Alexander T. Yong**, University of Minnesota.

Algebraic Methods in Statistics and Probability (Code: SS 3A), **Marlos A. G. Viana**, University of Illinois at Chicago.

Complex Dynamics and Value Distribution (Code: SS 11A), **Aimo Hinkkanen** and **Joseph B. Miles**, University of Illinois at Urbana-Champaign.

Geometric Function Theory and Analysis on Metric Spaces (Code: SS 6A), **Sergiy Merenkov**, **Jeremy Taylor Tyson**, and **Jang-Mei Wu**, University of Illinois at Urbana-Champaign.

Geometric Group Theory (Code: SS 2A), **Sergei V. Ivanov**, **Ilya Kapovich**, **Igor Mineyev**, and **Paul E. Schupp**, University of Illinois at Urbana-Champaign.

Graph Theory (Code: SS 4A), **Alexander V. Kostochka** and **Douglas B. West**, University of Illinois at Urbana-Champaign.

Holomorphic and CR Mappings (Code: SS 9A), **John P. D'Angelo**, **Jiri Lebl**, and **Alex Tumanov**, University of Illinois at Urbana-Champaign.

Local and Homological Methods in Commutative Algebra (Code: SS 13A), **Florian Enescu**, Georgia State University, and **Sandra Spiroff**, University of Mississippi.

Mathematical Visualization (Code: SS 7A), **George K. Francis**, University of Illinois at Urbana-Champaign, **Louis H. Kauffman**, University of Illinois at Chicago, **Dennis Martin Roseman**, University of Iowa, and **Andrew J. Hanson**, Indiana University.

Operator Algebras and Operator Spaces (Code: SS 8A), **Zhong-Jin Ruan**, **Florin P. Boca**, and **Marius Junge**, University of Illinois at Urbana-Champaign.

Probabilistic and Extremal Combinatorics (Code: SS 5A), **Jozsef Balogh** and **Zoltan Furedi**, University of Illinois at Urbana-Champaign.

Topological Field Theories, Representation Theory, and Algebraic Geometry (Code: SS 12A), **Thomas Nevins**, University of Illinois at Urbana-Champaign, and **David Ben-Zvi**, University of Texas at Austin.

q-Series and Partitions (Code: SS 1A), **Bruce Berndt**, University of Illinois at Urbana-Champaign, and **Ae Ja Yee**, Pennsylvania State University.

Raleigh, North Carolina

North Carolina State University

April 4–5, 2009

Saturday – Sunday

Meeting #1048

Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 4, 2008
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Invited Addresses

Nathan Dunfield, University of Illinois at Urbana-Champaign, *Title to be announced*.

Reinhard C. Laubenbacher, Virginia Biomathematics Institute at Virginia Tech, *Title to be announced*.

Jonathan C. Mattingly, Duke University, *Stochastically forced fluid equations: Transfer between scales and ergodicity*.

Raman Parimala, Emory University, *Title to be announced.*

Special Sessions

Applications of Algebraic and Geometric Combinatorics (Code: SS 2A), **Seth M. Sullivant**, Harvard University, and **Carla D. Savage**, North Carolina State University.

Enumerative Geometry and Related Topics (Code: SS 7A), **Richard L. Rimanyi**, University of North Carolina, Chapel Hill, and **Leonardo C. Mihalcea**, Duke University.

Homotopical Algebra with Applications to Mathematical Physics (Code: SS 3A), **Thomas J. Lada**, North Carolina State University, and **Jim Stasheff**, University of North Carolina, Chapel Hill.

Kac-Moody Algebras, Vertex Algebras, Quantum Groups, and Applications (Code: SS 1A), **Bojko N. Bakalov**, **Kailash C. Misra**, and **Naihuan N. Jing**, North Carolina State University.

Low Dimensional Topology and Geometry (Code: SS 4A), **Nathan M. Dunfield**, University of Illinois at Urbana-hampaign, **John B. Etnyre**, Georgia Institute of Technology, and **Lenhard Ng**, Duke University.

Recent Advances in Symbolic Algebra and Analysis (Code: SS 5A), **Michael F. Singer** and **Agnes Szanto**, North Carolina State University.

Rings, Algebras, and Varieties in Combinatorics (Code: SS 6A), **Patricia Hersh**, North Carolina State University, **Christian Lenart**, SUNY Albany, and **Nathan Reading**, North Carolina State University.

Worcester, Massachusetts

Worcester Polytechnic Institute

April 25–26, 2009

Saturday – Sunday

Meeting #1050

Eastern Section
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 25, 2008
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Octav Cornea, Université de Montréal, *Title to be announced.*

Fengbo Hang, Courant Institute of New York University, *Title to be announced.*

Umberto Mosco, Worcester Polytechnic Institute, *Title to be announced.*

Kevin Whyte, University of Illinois at Chicago, *Title to be announced.*

Special Sessions

Symplectic and Contact Topology (Code: SS 1A), **Peter Albers**, Courant Institute of Mathematical Sciences, and **Basak Gurel**, Université de Montréal.

The Mathematics of Climate Change (Code: SS 3A), **Catherine A. Roberts**, College of the Holy Cross, **Mary Lou Zeeman**, Bowdoin College, and **Gareth E. Roberts**, College of the Holy Cross.

Topological Robotics (Code: SS 2A), **Li Han** and **Lee N. Rudolph**, Clark University.

San Francisco, California

San Francisco State University

April 25–26, 2009

Saturday – Sunday

Meeting #1049

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 25, 2008
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Yehuda Shalom, University of California Los Angeles, *Title to be announced.*

Roman Vershynin, University of California Davis, *Title to be announced.*

Karen Vogtmann, Cornell University, *Title to be announced.*

Efim Zelmanov, University of California Los Angeles, *Title to be announced.*

Special Sessions

Banach Algebras, Topological Algebras and Abstract Harmonic Analysis (Code: SS 1A), **Thomas V. Tonev**, University of Montana-Missoula, and **Fereidoun Ghahramani**, University of Manitoba.

Concentration Inequalities (Code: SS 3A), **Sourav Chatterjee**, University of California Berkeley, and **Roman Vershynin**, University of California Davis.

Recent Progress in Geometric Group Theory (Code: SS 2A), **Seonhee Lim** and **Anne Thomas**, Cornell University.

Waco, Texas

Baylor University

October 16–18, 2009

Friday – Sunday
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 17, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

David Ben-Zvi, University of Texas at Austin, *Title to be announced.*

Alexander A. Kiselev, University of Wisconsin, *Title to be announced.*

Michael C. Reed, Duke University, *Title to be announced.*

Igor Rodnianski, Princeton University, *Title to be announced.*

Special Sessions

Dynamic Equations on Time Scales: Analysis and Applications (Code: SS 1A), **John M. Davis**, **Ian A. Gravagne**, and **Robert J. Marks**, Baylor University.

Mathematical Models of Neuronal and Metabolic Mechanisms (Code: SS 3A), **Janet Best**, Ohio State University, and **Michael Reed**, Duke University.

Numerical Solutions of Singular or Perturbed Partial Differential Equation Problems with Applications (Code: SS 2A), **Peter Moore**, Southern Methodist University, and **Qin Sheng**, Baylor University.

Boca Raton, Florida

Florida Atlantic University

October 30 – November 1, 2009

Friday – Sunday
Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 30, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see `www.ams.org/amsmtgs/sectional.html`.

Invited Addresses

Spyros Alexakis, Princeton University, *Title to be announced.*

Kai-Uwe Bux, University of Virginia, *Title to be announced.*

Dino J. Lorenzini, University of Georgia, *Title to be announced.*

Eduardo D. Sontag, Rutgers University, *Title to be announced.*

Special Sessions

Constructive Mathematics (Code: SS 1A), **Robert Lubarsky**, **Fred Richman**, and **Martin Solomon**, Florida Atlantic University.

Riverside, California

University of California

November 7–8, 2009

Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 6, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

The scientific information listed below may be dated. For the latest information, see www.ams.org/amsmtgs/sectional.html.

Special Sessions

Algebraic Geometry (Code: SS 1A), **Christopher Hacon**, University of Utah, and **Ziv Ran**, University of California Riverside.

Noncommutative Geometry (Code: SS 2A), **Vasiliy Dolgushev** and **Wee Liang Gan**, University of California Riverside.

San Francisco, California

Moscone Center West and the San Francisco Marriott

January 6–9, 2010

Wednesday – Saturday
Joint Mathematics Meetings, including the 116th Annual Meeting of the AMS, 93rd Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society of Industrial and Applied Mathematics (SIAM).
Associate secretary: Matthew Miller
Announcement issue of *Notices*: October 2009
Program first available on AMS website: November 1, 2009
Program issue of electronic *Notices*: January 2010
Issue of *Abstracts*: Volume 31, Issue 1

Deadlines

For organizers: April 1, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Lexington, Kentucky

University of Kentucky

March 27–28, 2010

Saturday – Sunday
Southeastern Section
Associate secretary: Matthew Miller
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 28, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

St. Paul, Minnesota

Macalester College

April 10–11, 2010

Saturday – Sunday
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 10, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Albuquerque, New Mexico

University of New Mexico

April 17–18, 2010

Saturday – Sunday
Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 17, 2009
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Notre Dame, Indiana

Notre Dame University

September 18–19, 2010

Saturday – Sunday
Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: February 19, 2010
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

New Orleans, Louisiana

New Orleans Marriott and Sheraton New Orleans Hotel

January 5–8, 2011

Wednesday – Saturday
Joint Mathematics Meetings, including the 117th Annual Meeting of the AMS, 94th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: October 2010
Program first available on AMS website: November 1, 2010
Program issue of electronic *Notices*: January 2011
Issue of *Abstracts*: Volume 32, Issue 1

Deadlines

For organizers: April 1, 2010
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Boston, Massachusetts

John B. Hynes Veterans Memorial Convention Center, Boston Marriott Hotel, and Boston Sheraton Hotel

January 4–7, 2012

Wednesday – Saturday
Joint Mathematics Meetings, including the 118th Annual Meeting of the AMS, 95th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: October 2011
Program first available on AMS website: November 1, 2011
Program issue of electronic *Notices*: January 2012
Issue of *Abstracts*: Volume 33, Issue 1

Deadlines

For organizers: April 1, 2011
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

San Diego, California

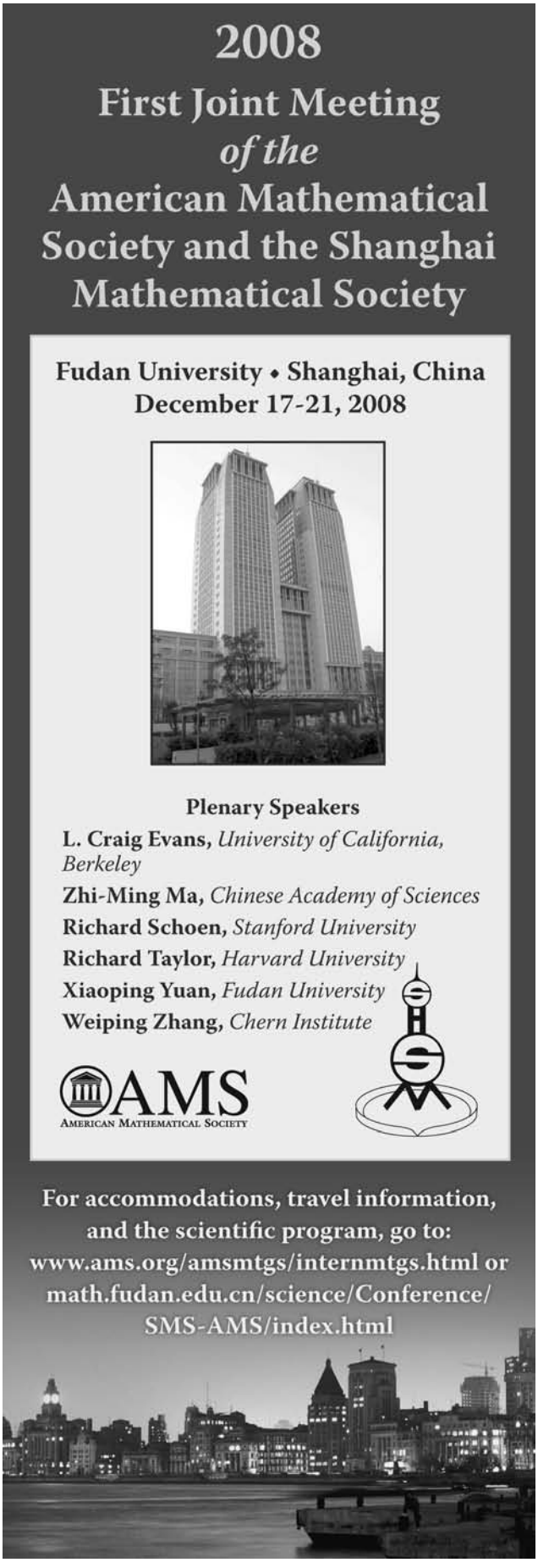
San Diego Convention Center and San Diego Marriott Hotel and Marina

January 9–12, 2013

Wednesday – Saturday
Joint Mathematics Meetings, including the 119th Annual Meeting of the AMS, 96th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL), with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).
Associate secretary: Steven H. Weintraub
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 1, 2012
For consideration of contributed papers in Special Sessions: To be announced



For abstracts: To be announced

Baltimore, Maryland

Baltimore Convention Center

January 15–18, 2014

Wednesday – Saturday

Joint Mathematics Meetings, including the 120th Annual Meeting of the AMS, 97th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Matthew Miller

Announcement issue of *Notices*: To be announced

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: To be announced

Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 1, 2013

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

San Antonio, Texas

Henry B. Gonzalez Convention Center and Grand Hyatt San Antonio

January 10–13, 2015

Saturday – Tuesday

Joint Mathematics Meetings, including the 121st Annual Meeting of the AMS, 98th Annual Meeting of the Mathematical Association of America, annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association of Symbolic Logic, with sessions contributed by the Society for Industrial and Applied Mathematics (SIAM).

Associate secretary: Susan J. Friedlander

Announcement issue of *Notices*: October 2014

Program first available on AMS website: To be announced

Program issue of electronic *Notices*: January 2015

Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 1, 2014

For consideration of contributed papers in Special Sessions: To be announced

For abstracts: To be announced

Meetings and Conferences of the AMS

Associate Secretaries of the AMS

Western Section: Michel L. Lapidus, Department of Mathematics, University of California, Surge Bldg., Riverside, CA 92521-0135; e-mail: lapidus@math.ucr.edu; telephone: 951-827-5910.

Central Section: **Susan J. Friedlander**, Department of Mathematics, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607-7045; e-mail: susan@math.nwu.edu; telephone: 312-996-3041.

Eastern Section: **Lesley M. Sibner** (until January 31, 2009), Department of Mathematics, Polytechnic University, Brooklyn, NY 11201-2990; e-mail: lsibner@duke.poly.edu; telephone: 718-260-3505. **Steven H. Weintraub** (after January 31, 2009), Department of Mathematics, Lehigh University, Bethlehem, PA 18105-3174; e-mail: steve.weintraub@lehigh.edu; telephone: 610-758-3717.

Southeastern Section: **Matthew Miller,** Department of Mathematics, University of South Carolina, Columbia, SC 29208-0001, e-mail: miller@math.sc.edu; telephone: 803-777-3690.

2009 Washington, DC, Meeting: Bernard Russo, Department of Mathematics, University of California, Irvine, CA 92697-3875, e-mail: brusso@math.uci.edu; telephone: 949-824-5505.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information can be found at** www.ams.org/meetings/.

Meetings:

2008		
October 4–5	Vancouver, Canada	p. 887
October 11–12	Middletown, Connecticut	p. 890
October 17–19	Kalamazoo, Michigan	p. 892
October 24–26	Huntsville, Alabama	p. 895
December 17–21	Shanghai, People's Republic of China	p. 897
2009		
January 5–8	Washington, DC Annual Meeting	p. 898
March 27–29	Urbana, Illinois	p. 905
April 4–5	Raleigh, North Carolina	p. 905
April 25–26	San Francisco, California	p. 906
April 25–26	Worcester, Massachusetts	p. 906
Oct. 16–18	Waco, Texas	p. 907
Oct. 30–Nov. 1	Boca Raton, Florida	p. 907
Nov. 7–8	Riverside, California	p. 907
2010		
January 6–9	San Francisco, California Annual Meeting	p. 908
March 27–28	Lexington, Kentucky	p. 908
April 10–11	St. Paul, Minnesota	p. 908
April 17–18	Albuquerque, New Mexico	p. 908
September 18–19	Notre Dame, Indiana	p. 909
2011		
January 5–8	New Orleans, Louisiana Annual Meeting	p. 909
2012		
January 4–7	Boston, Massachusetts Annual Meeting	p. 909
2013		
January 9–12	San Diego, California Annual Meeting	p. 909
2014		
January 15–18	Baltimore, Maryland Annual Meeting	p. 910
2015		
January 10–13	San Antonio, Texas Annual Meeting	p. 910

Important Information Regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 95 in the January 2008 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Speakers should submit abstracts on the easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding, and all math displays and similarly coded material (such as accent marks in text) must be typeset in LaTeX. Visit http://www.ams.org/cgi-bin/abstracts/abstract.pl. Questions about abstracts may be sent to abs-info@ams.org. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

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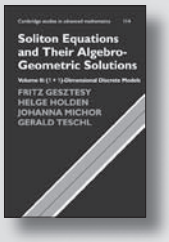

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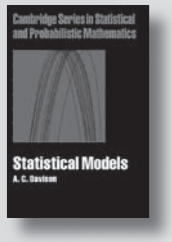

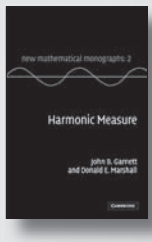

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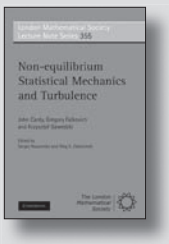

Forthcoming!

Non-equilibrium Statistical Mechanics and Turbulence
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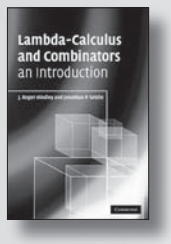

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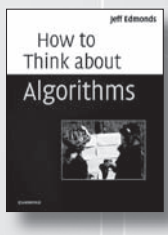

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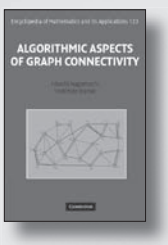

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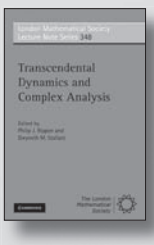

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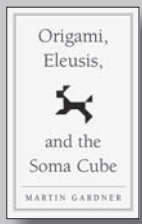

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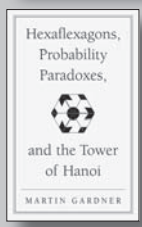

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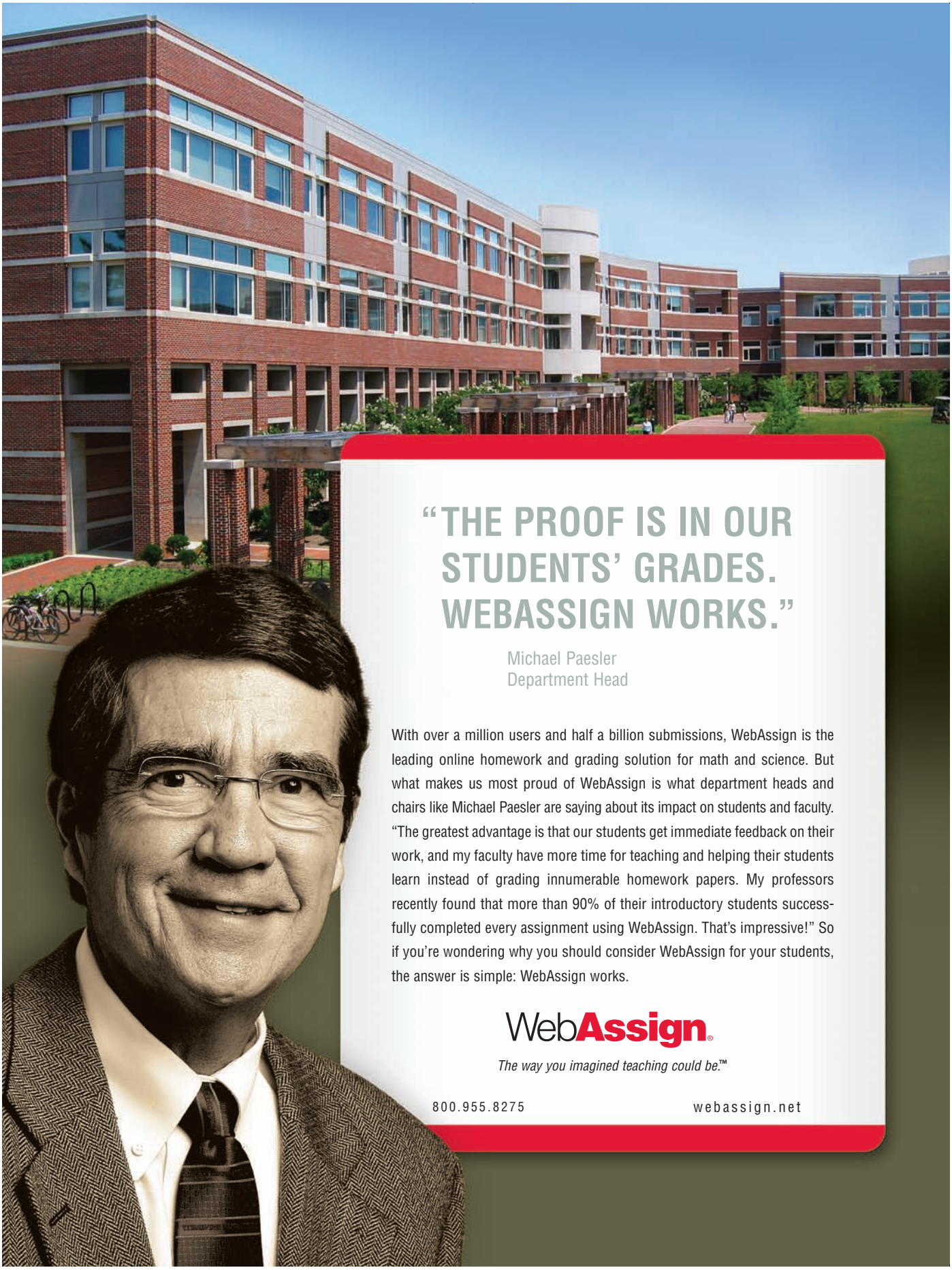

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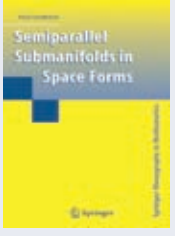

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Ülo Lumiste, University of Tartu, Estonia

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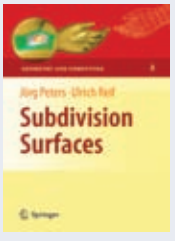

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J. Peters, University of Florida, Gainesville, FL, USA; **U. Reif**, TU Darmstadt, Germany

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